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# A SURVEY AND TECHNICAL SYSTEMS ASSESSMENT OF DRONE AIRCRAFT FOR TACTICAL RECONNAISSANCE AND SURVEILLANCE (U)

(Volume I, Task No. A-3759)

by


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and R. D. Minckler



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## FOREWORD (U)

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(U) This report, A Survey and Technical Assessment of Drone Aircraft Systems for Tactical Reconnaissance and Surveillance (Volume I), is supplemented by a Characteristics Handbook of Drone Flight Vehicles (U) (Volume II). These two documents constitute the final report on this project for ARPA.

## ACKNOWLEDGMENTS (U)

(U) The authors wish to express their particular appreciation of the assistance provided by Messrs. R. W. Baker and F. A. Tietzel in the survey of drone aircraft systems and in the preparation of the Handbook. Their technical contributions and timely suggestions were most helpful in creating the final product.

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(U) The views and conclusions contained in this document are those of the authors and should not necessarily be interpreted as representing the official policies, either expressed or implied, of the Advanced Research Projects Agency or the U. S. Government.

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# A SURVEY AND TECHNICAL ASSESSMENT OF DRONE AIRCRAFT SYSTEMS FOR TACTICAL RECONNAISSANCE AND SURVEILLANCE (U)

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## INTRODUCTION (U)

(U) At the request of Dr. Charles H. Church of the Tactical Technology Office, Advanced Research Projects Agency (ARPA), Battelle's Tactical Technology Center (TACTEC) initiated a state-of-the-art survey and technical assessment of drone aircraft systems in April, 1971. The project was defined and established within the framework of an existing ARPA contract with Battelle-Columbus for analytic support. The objectives of the project were to:

- Conduct a survey of existing and developmental drone aircraft with emphasis on systems that might be used as aerial platforms for reconnaissance-and-surveillance (R&S) missions. However, no drones were excluded simply because their primary roles were not R&S.
- Present selected information on the drone aircraft systems in the form of a suitable handbook.
- Perform a technical assessment to assist interested agencies in the:
  - Identification of drones that may be suitable for R&S missions.
  - Determination of appropriate courses of action in developing or adapting drone aircraft systems for these missions.

(U) The survey was based upon all available relevant literature and upon contacts and visits with the Military Services and with selected developers and manufacturers, both U. S. and foreign.* Initially, the survey was directed toward drones having a gross weight of not more than 3000 pounds. This constraint was subsequently removed as vehicles of interest to ARPA and exceeding this weight were identified. The results of the survey are presented in the Characteristics Handbook of Drone Flight Vehicles, Volume II of this final report.

(U) This report (Volume I) includes an overall summary of the program, a technical assessment of the current status of drone aircraft for R&S missions, and some observations and recommendations with respect to the goals and technical objectives of future systems. Appendices, in addition to the two already mentioned cover the history of drone development in the Army, and assessment of tethered and hovering flight platforms and small, inexpensive drones.

*A summary of the visits and contacts made during the course of the survey is included as Appendix A to this report. Comments upon foreign development activities are provided in Appendix B.

## PROGRAM SUMMARY (U)

(U) During the course of the program, it was determined that certain drone aircraft systems/concepts should not be included in the Handbook because development efforts were not initiated, were quite limited, were cancelled before significant progress was achieved, are now seriously lagging, or are not yet sufficiently documented. However, some of these systems are discussed briefly in this assessment. One nondrone aircraft, the BD-5A, was also included because it appears to have unique potential for drone applications.

(U) A summary of selected data for most of the vehicles included in the Handbook is presented in Table 1. The Handbook, however, should be consulted for more complete and definitive data. Data in the Handbook covers several groups of closely related vehicles, but, in most instances, only one representative example of these vehicles has been included in the table. In order to keep the table unclassified, no data are given for drones of the 147 and 154 series.

(U) To the reader who is conversant with the older designations of drone aircraft systems, it may appear that many of the drones with which they are familiar were omitted from the Handbook and technical assessment. These drones, however, are included under their newer designations. Table 2 provides a cross reference index between the old and new designations.

(U) At the outset of this research program, there was some concern that it might duplicate other surveys, such as those performed by the Army Electronics Command (ECOM), Army Foreign Science and Technology Center (FSTC), Naval Research Laboratory (NRL), Canadian Ministry of Defence, and Central Intelligence Agency (CIA). However, during the course of the program, it became apparent that these earlier surveys were either quite limited in scope or out-of-date.

### Observations (U)

(C) A summary of the observations and general courses of recommended action generated by the technical assessment is given below:

- Major problems encountered with tactical R&S drones in the past have involved the complexity and burden of the support systems, excessive vehicle and system costs, limited mission versatility, and minimal or untimely data collection.

- Remotely Piloted Vehicle (RPV) developments are expected to lead the way in providing new capabilities for tactical R&S. It is expected that the vehicles based upon present RPV or tactical missile developments will assume missions previously identified with tactical R&S drones.

TABLE 1. DRONE VEHICLE SYNOPSIS (U)

| Drone Vehicle | Nominal Range | Mission Endurance | Gross Weight, lb | Typical Mission Velocity | Altitude Capability, ft | Mission Type | Vehicle Status | Vehicle Popular Name | Propulsion System Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| BQM-6C | 575 mi | -- | 14,522 | M = 0.87 | -- | Target vehicle (drone version) | Out of production and out of use | Regulus I | Turbojet | -- |
| CQM-10A | 230 nm | 8 min | 16,000 | M = 2.65 | 67,000 | Target vehicle (drone version) | In use at PMR | Bomarc | Ramjet | -- |
| MQM-13A | -- | -- | 18,000 | -- | -- | Target vehicle (drone version) | Out of use | MACE A | Turbojet | -- |
| MQM-15A | -- | 1 hr | 21,000 | M = 2.0 | 55,000 | Target vehicle (drone version) | Out of use | Regulus II | Turbojet | -- |
| MQM-33A | -- | 1 hr | 333 | 200 mph | 23,000 | Gunnery target | Active use | Creeper | Reciprocating | -- |
| MQM-33B | -- | -- | -- | -- | -- | -- | -- | -- | -- | See MQM-33A |
| MQM-33C | -- | -- | -- | -- | -- | -- | -- | -- | -- | See MQM-36A |
| BQM-34A | -- | 1hr | 2,300 | 707 mph | 60,000 | Target vehicle | Active use | Firebee I | Turbojet | -- |
| AQM-34B | -- | -- | -- | -- | -- | -- | -- | -- | -- | See BQM-34A |
| AQM-34C | -- | 1 hr | 1,940 | 575 mph | 45,000 | Navy target | Out of service | Firebee I | Turbojet | -- |
| MQM-34D | -- | -- | -- | -- | -- | Army target | Active use | Firebee I | Turbojet | Performance similar to BQM-34A |
| BQM-34E | -- | 1.5 hr | 2,310 | M = 1.5 | 60,000 | Subsonic/supersonic target | Operational with USN | Firebee II | Turbojet | -- |
| BQM-34F | -- | -- | -- | -- | -- | -- | To be operational USAF | -- | -- | See BQM-34E |
| AQM-35A/B | 325 nm (radius) | -- | 3,555 | M = 2.0 | 70,000 | Supersonic target vehicle | Out of use | -- | Turbojet | -- |
| MQM-36A | 202 mi | 1 hr | 340 | 202 mph | 23,000 | Gunnery and missile target | Active use | -- | Reciprocating | -- |
| AQM-37A | 114 nm | 5.5 min | 562 | M = 2 | 70,000 | High-speed target, USN | Active use | -- | Liquid Rocket | -- |
| AQM-38A/B | -- | 5 min | 290 | M = 2 | 70,000 | High-speed target | Out of use | -- | Solid rocket | -- |
| MQM-39A | -- | 1 hr | 590 | 350 mph | 40,000 | Target vehicle | See MQM-61A | -- | Reciprocating | Early version of 61A |
| AQM-41A | -- | 25 min | 3,900 | 325 kts | Low/Deck | Low-altitude target | Out of use | Petrel | Turbojet | Flying torpedo |
| MQM-42A | -- | 2.6 min | 765 | M = 0.9 to 1.57 | 15,000 | Dual speed/altitude target | Renewed testing | Redhead/ Roadrunner | Ramjet | -- |
| PQM-56A | -- | 14 min | 6,615 | M = 2.7 | 65,000 | Supersonic target, USN | Not in production | -- | Ramjet | Nord CT.41 |
| MQM-57A | 92 mi (radius) | 30 min | 448 | 166 mph | 15,000 | Battlefield surveillance | Out of use | Falconer | Reciprocating | Based upon the MQM-36A |
| MAM-57B | -- | -- | -- | -- | -- | -- | -- | -- | -- | Improved electronics - See MQM-57A |

TABLE 1. (Continued) (U)

| Drone Vehicle | Nominal Range | Mission Endurance | Gross Weight, lb | Typical Mission Velocity | Altitude Capability, ft | Mission Type | Vehicle Status | Vehicle Popular Name | Propulsion System Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| MQM-58A | 177 mi | 85 min | 1,400 | 270 kts | 20,000 | Battlefield surveillance | Out of use | Overseer | Reciprocating | -- |
| AQM-60A | -- | -- | 7,600 | M = >2 | -- | Target vehicle (drone version) | Out of use | Kingfisher | Ramjet | -- |
| MQM-61A | -- | 1 hr | 664 | 305 kts | 44,000 | Target drone, U. S. Army | Active use | Cardinal | Reciprocating | -- |
| MQM-74A | -- | 74 min | 385 | 400 kts | 35,000 | Target drone – USN | Active use | Chuckar | Turbojet | -- |
| AQM-81A | -- | 4.73 min | 633 | M = 4.28 | 90,000 | High performance target | Developmental | Sandpiper | Hybrid Rocket | -- |
| XQM-93A | -- | 18 hr | 4,600 | -- | 50,000 | Electronics relay platform | Active use | Compass Dwell | Turboprop | -- |
| QU-22B | -- | 6 hr | 5,000 | 208 KIAS | 30,000 | Electronics relay platform | Active use | Pave Eagle | Reciprocating | -- |
| QT-33A | -- | 90 min | 15,000 | M = 0.8 | 30,000 | Real-sized target aircraft | Active | Shooting Star | Turbojet | -- |
| QF-9J | -- | 90 min | 19,500 | 380 kts | 35,000 | Real-sized target aircraft | Being replaced by QT-33A | Cougar | Turbojet | -- |
| QF-4B | 540 nm | 30 min | 42,505 | M = 2.2 | 58,000 | Real-sized target aircraft | Scheduled for use in 1971 | Phantom II | Turbojet | -- |
| QF-104A | -- | 2 hr | 23,820 | M = 2 | 52,000 | Real-sized target aircraft | Active use | Starfighter | Turbojet | -- |
| QP-4B | -- | 2 hr | 65,000 | 160 kts | 15,000 | Large-sized target aircraft | Out of use | -- | Reciprocating | -- |
| QH-50A | -- | 90 min | 825 | 45 kts | 1,500 (max.) | Drone target at NMC Anti-submarine helicopter | Active use | DASH | Reciprocating | Original QH-50 evaluation prototype |
| QH-50C | 82 mi | 1 hr | 2,285 | 92 mph | 16,400 | Anti-submarine helicopter | Out of use | DASH | Turboshaft | -- |
| QH-50D | -- | 1.73 hr | 2,330 | 90 mph | 16,000 | Anti-submarine helicopter test platform | In use as platform – Nite Gazelle/Nite Panther | DASH | Turboshaft | -- |
| 147/154 | -- | -- | -- | -- | -- | -- | -- | -- | -- | See Handbook |
| HAST | -- | 5 min | 1,145 | M = 4 | 100,000 | High performance, tri-service target | Developmental | -- | Hybrid Rocket | -- |
| Beech 1055 | -- | 82 min | 1,125 | 400 kts | 40,000 | Medium high performance | Development dormant | -- | Turbojet | See MQM-39A/ MQM-61A |
| Whirlymite DH-2C/DH-2D/ DH-2E | 100 mi | -- | 650 | 90 mph | 13,000 | Versatile small drone helicopter platform | Developmental-Limited use | -- | Turboshaft | -- |
| NV-113 | 720 nm | >1 hr | 594 | 420 kts | 34,500 | Reconnaissance version of MQM-74A | Proposed | -- | Turbojet | -- |

TABLE 1. (Continued) (U)

| Drone Vehicle | Nominal Range | Mission Endurance | Gross Weight, lb | Typical Mission Velocity | Altitude Capability, ft. | Mission Type | Vehicle Status | Vehicle Popular Name | Propulsion System Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Compass Cope | -- | 36 hr | 12,000 | -- | >55,000 | Strategic reconnaisance and relay | Developmental | -- | Turbofan | -- |
| Bikini | 20 nm | 30 min | 60 | 100 mph | 10,000 | Short range reconnaisance - USMC | Out of use | -- | Reciprocating | -- |
| Owl | 200 nm | 2 hr | 900 | 110 kts | 15,000 | Low/slow covert reconnaissance drone | Predevelopmental | -- | Wankel | -- |
| SD-3 | -- | 85 min | 1,000 | 270 kts | 20,000 | All-weather combat surveillance | Project terminated | Snooper | Reciprocating | Performance objectives were similar to MQM-58A |
| SD-4 | 340 nm | -- | 3,948 | M = 1.35 | 40,000 | All-weather combat surveillance | Project terminated | Swallow | Turbojet | -- |
| SD-5 | 1,050 nm | 4 hr | 8,600 | M = 0.85 | 40,000 | All-weather combat surveillance | Project terminated | Osprey | Turbojet | -- |
| BD-5A | 670 mi | -- | 450 | 197 mph | 12,000 | Low cost manned aircraft | Developmental | Micro | Reciprocating | -- |
| Turana | -- | 1 hr | 440 | 450 kts | 35,000 | Drone version of Ikara missil | Developmental | -- | Turbojet | Australian |
| Jindivik MK-3A (see LTV MK303A | 820 mi | 5 hr | 3,600 | 564 mph | 62,000 | Target vehicle | Active use | -- | Turbojet | Australian |
| Jindivik MK-3B | -- | -- | 3,650 | -- | -- | Target vehicle | Active use | -- | Turbojet | Australian - See MK-3A for general performance |
| Epervier X-4 | 44 mi | >1 hr | 306 | 336 mph | 19,080 | Battlefield surveillance drone | Development dormant | -- | Turbojet | Belgium |
| Epervier Prop. Version | -- | 1 hr | 200 | 230 mph | 13,000 | Battlefield surveillance drone | Superseded by X-4 | -- | Wankel | Belgium |
| CL-89 | 75 mi | 8 min | 343 | 470 mph | 10,000 | Short range reconnaissance | In production | -- | Turbojet | Canada |
| Kiebitz | -- | 24 hr | 464 | N/A | 3,280 | Versatile tethered platform | Developmental | -- | Turbo-compressor | FDRG |
| Aerodyne | -- | -- | -- | M = .6 | -- | V/STOL surveillance platform | Development dormant | -- | Turboshaft | FDRG - Limited data available |
| KAD | 500 mi | -- | 6,150 | 650 mph | 36,808 | Medium range area reconnaissance | Development dormant | -- | Turbojet | FDRG - Has unique rotary wing mode |
| Nord CT. 20 | 250 mi | 1 hr | 1,600 | 560 mph | 32,500 | Target drone | Active use | -- | Turbojet | France |
| R. 20 | 192 mi | 1 hr | 1,870 | 510 mph | 32,500 | Battlefield reconnaissance | Active use | -- | Turbojet | France |

TABLE 1. (Continued) (U)

| Drone Vehicle | Nominal Range | Mission Endurance | Gross Weight, lb | Typical Mission Velocity | Altitude Capability, ft. | Mission Type | Vehicle Status | Vehicle Popular Name | Propulsion System Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SD.2 Stiletto | -- | -- | -- | -- | -- | -- | -- | -- | -- | U.K. – Version of AQM-37A |
| Meteor P.1 | 100 mi | 1 hr | 500 | 340 mph | 42,000 | Target drone | Active use | -- | Reciprocating | Italy |
| Meteor P.1/R | 62 mi | 1 hr | 551 | 310 mph | 30,000 | Reconnaissance version of P.1 | Active use | -- | Reciprocating | Italy |
| KAQ-5 | -- | 8 min | 375 | M = .8 | 40,000 | Target drone | Active use | -- | S. Rocket | Japan |

TABLE 2. CROSS-REFERENCE OF OLD AND NEW DRONE DESIGNATIONS[a] (U)

| | Old Designation | New Designation |
|---|---|---|
| KD Series | KDA-1 | AQM-34B |
| | KDA-4 | AQM-34C |
| | KDB-1 | MQM-39A |
| | KD2B-1 | AQM-37A |
| | KD2R-3 | -- |
| | KD2R-5 | MQM-36A |
| | KDU-1 | BQM-6C |
| | KD2U-1 | MQM-15A |
| OQ Series | OQ-19B | MQM-33A |
| | OQ-19D | MQM-33B |
| | OQ-19E | MQM-36A |
| Q Series | Q-2A | AQM-34B |
| | Q-2C | BQM-34A |
| | Q-4 | -- |
| | Q-4A | AQM-35A |
| | Q-4B | AQM-35B |
| | Q-5 | AQM-60A |
| | Q-12 | AQM-37A |
| SD Series | AN/USD-1 | -- |
| | AN/USD-1A | MQM-57A |
| | AN/USD-1B | MQM-57B |
| | AN/USD-2 | MQM-58A |
| | AN/USD-3 | -- |
| | AN/USD-4 | -- |
| | AN/USD-5 | -- |

(a) New designations are used throughout this report.

- The tactical R&S drones now in service or under development are all foreign vehicles. There are, however, a few proposed or pre-developmental U. S. vehicles that could be used in this role. None of these systems, foreign or U. S., have, or will have, the capability for active vehicle control and real-time-data reporting that is reflected in current RPV objectives.

- Helicopter-type drones could provide a significant interim capability while RPV technology advances toward application to tactical reconnaissance and surveillance. The major advantages of this type of vehicle are hover capability, reduction of support requirements, and elimination of parachute recovery.

- Tethered-flight platforms are not currently considered to have a viable future. Their potential advantages are long endurance, minimum support equipment, and quick response, but overriding disadvantages at the present time are their limited range of observation and payload. To date, major technical problems have plagued the development of this type of vehicle.

- Long-range, advanced-strategic-reconnaissance drones and long-endurance, electronics-relay platforms do not make a direct technical contribution to the improvement of tactical R&S vehicles.

## General Courses of Recommended Action (U)

- Drone-aircraft system development for tactical R&S missions have been deficient in the conceptual phases. Future developments should emphasize design for optimum cost, environmental compatibility, control versatility, and real-time data reporting.

- The current technology in propulsion systems, structures, airframes, and even in navigation/control systems and mission sensors is adequate for the development of superior tactical surveillance RPVs at the present time. Technical refinements are desirable in all sub-elements, but cost-reduction efforts deserve greater priority than performance improvements per se.

- Cost-reduction efforts should look toward the goal of expendable tactical R&S vehicles.

## Current DoD Activities Related to the Development of Tactical Reconnaissance and Surveillance Drone Aircraft Systems (U)

(U) There are currently no U. S.-developed drone vehicles in active use for tactical R&S missions. The few older vehicles that were developed for these missions are no longer operational. Two older foreign vehicles (the R.20 and the Meteor P. 1/R) are still being used by foreign countries for tactical R&S, and the Canadian CL-89 is a candidate for operational use by a number of countries. There are, however, a number of current U. S. activities with respect to the development of drone vehicles for the tactical R&S role and for the overall aerial R&S mission; for example:

- At the Department of Defense (Director of Defense Research & Engineering) level, the preparation and publication of an Area Coordination Paper (ACP) on the RDT&E associated with aerial R&S systems is of primary importance from the point of view of the overall coordination of U. S. efforts in this field.

- The Army, after being the front-runner in the field of tactical-surveillance drone systems, is now reassessing and restating its drone-aircraft surveillance-systems requirements. This is reflected in the Qualitative Materiel Development Objective (QMDO) for an Unattended Aerial Surveillance System, the Threat to Aerial Reconnaissance and Surveillance Systems Survey, 1968-1975 (TARS-75), the Elevated Target Acquisition System (ELTAS) concept paper, and the STANO Resource Management Study.

- The Marine Corps is also in the process of reassessing and restating its drone-aircraft surveillance-systems requirements. The Special Studies Group at the Naval Research Laboratory has just completed a somewhat limited, unclassified survey of drone-aircraft systems for the Marine Corps and is now looking at the field of airborne sensors.

- The Navy has a strong RPV RDT&E program.

## TECHNICAL ASSESSMENT (U)

(U) The principal purpose of this technical assessment is to aid in identifying drones that may be suitable for tactical R&S missions and to help determine what courses of action should be considered in developing new drones, or adapting existing drones, for these missions. This section presents an assessment of current drone systems that have potential for tactical R&S missions. A discussion of future courses of action for development and adaptation of drones for tactical R&S missions is presented under Recommendations.

(U) During the course of this program, information was developed on tethered and hovering observation flight platforms and on some very small, simple, and inexpensive drone systems. These systems are not considered to be within the scope of this study, and accordingly they are not covered in either the Technical Assessment or in the accompanying Handbook (Volume II). However, some discussion and information on them is included as Appendices D and E to this report.

## Candidate Vehicles for Tactical R&S Missions (U)

(U) Of the 81 different drone-vehicle designations included in the Handbook, a great many are unsuitable for tactical R&S missions. These include vehicles which:

- have too high speed and/or unsuitably short flight times
- are near-duplicates of more suitable drones
- represent outdated technology
- have limited versatility
- have excessive cost, support requirements, and/or vulnerability.

In identifying drones which may be suitable for tactical R&S missions, we started with all the drones listed in the Handbook and successively eliminated those which are unsuitable for the aforementioned reasons, to arrive at a list of potential tactical R&S drones.

### Speed/Range Limitations (U)

(U) One group of vehicles that can be eliminated is the high-speed, generally rocket- or ramjet-powered, target drones, as listed in Table 3. Their high speed and short flight duration capability make them unsuitable. Although there may be unique R&S requirements or technology cross-fertilization opportunities that could cause reconsideration of these vehicles, they are generally unsuitable.

(U) Table 3 contains all of the rocket and ramjet powered vehicles listed in Table 1. The AQM-35 turbojet-powered vehicle has also been included in this list. The vehicle has a limited use history and should not be considered to offer any potential not surpassed by the now current BQM-34E.

(U) The KAQ-5 is the only subsonic vehicle included in this list. Its limited flight time and typical high-altitude, target-type trajectory suggests that it would lack the versatility for use in a R&S role. One feature of the KAQ-5 that is unique in the drone group and that could be suitable for other low-cost, short-range drones is the slow-burning, solid-propellant motor that is used. The motor is produced by the Dainippon Celluloid Company in Osaka. It is reported to burn for the entire 8 minutes of the KAQ-5 flight. Early reports on tests of this motor claimed that it burned at an even rate for this period.

TABLE 3. DRONES UNSUITABLE FOR TACTICAL R&S MISSIONS DUE TO HIGH-SPEED AND SHORT-FLIGHT-DURATION MISSIONS (U)

| Drone Designation | Mach No. | Flight Duration | Propulsion |
|---|---|---|---|
| CQM-10A (Bomarc) | 2.65 | 8 min | Ramjet |
| AQM-37A | 2 | 5.5 min | Liquid rocket |
| AQM-38A&B | 2 | 5 min | Solid rocket |
| MQM-42A (Redhead/ Roadrunner) | 1.57 | 2.6 min | Ramjet |
| PQM-56A (Nord CT.41) | 2.7 | 14 min | Ramjet |
| AQM-60A (Kingfisher) | >2 | Short | Ramjet |
| AQM-81A (Sandpiper) | 4.3 (max) | 4.73 min | Hybrid rocket |
| HAST (High Altitude Supersonic Target) | 4 | 5 min | Hybrid rocket |
| SD.2 Stiletto (British version of AQM-37A above) | | | |
| KAQ-5 | 0.87 | 8 min | Solid rocket |
| AQM-35A/B | 2 | Short | Turbojet |

Near Duplicates of More Suitable Drones (U)

(U) In the Handbook, an effort was made to present a complete spectrum of vehicles, including all of the various modifications and improvements that have existed because of differing launch modes and different service uses of the vehicles. In this assessment, however, it is not necessary to continue to account for all of these variations so long as the most representative or highest performance vehicle can be identified in these families. On this basis, a number of designations and/or vehicles can be neglected. These are listed in Table 4. This procedure allows 32 vehicle designations to be suitably represented by 12 vehicles.

TABLE 4. DRONES THAT ARE NEAR DUPLICATES OF MORE SUITABLE DRONES (U)

| Vehicle to be Disregarded | Adequately Represented By |
|---|---|
| MQM-33A | MQM-36A |
| MQM-33B | MQM-36A |
| MQM-33C | MQM-36A |
| AQM-34B | BQM-34A |
| MQM-34D | BQM-34A |
| AQM-34C | BQM-34A |
| BQM-34F | BQM-34E |
| MQM-39A | MQM-61A |
| MQM-57A | MQM-57B |
| MQM-74A | NV-113 |
| QH-50C | QH-50D |
| QH-50A | QH-50D |
| Whirlymite Series (DH-2C, 2D) | DH-2E |
| Jindivik MK 3B | Jindivik MK 3A |
| Epervier (Prop. version) | Epervier X-4 |
| Nord CT.20 | Nord R.20 |
| Meteor P.1 | Meteor P.1/R |

Drones Representing Outdated Technology (U)

(U) The old, heavy, target drones that resulted from converting the Regulus, MACE, and Bomarc missiles to drone versions are generally out of use.* In general, the technology represented by these vehicles is outdated. They are extremely large and heavy and they require major support complexes and large crews. In addition, they are out of production and were expensive to produce originally. Consequently, their potential for any current R&S requirement, tactical or strategic, is judged to be extremely low. Drones falling in this category are listed in Table 5.

*An exception is the Bomarc drone version which is still in occasional use at the Pacific Missile Range. However, it represents outdated technology from the standpoint of the tactical R&S mission.

TABLE 5. DRONES UNSUITABLE FOR TACTICAL R&S MISSIONS DUE TO OUTDATED TECHNOLOGY FOR THIS APPLICATION (U)

| |
|---|
| BQM-6C (Regulus I) |
| MQM-15A (Regulus II) |
| CQM-10A (Bomarc) |
| MQM-13A (MACE A) |

Drones With Limited Versatility (U)

(U) There is one vehicle covered in the Handbook that is judged to have such limited versatility that it too should be disregarded. This is the Petrel, AQM-41A. The Petrel target-drone version was derived from the flying-torpedo weapon system. The Petrel was essentially a torpedo with a strap-on turbojet propulsion system.

Drones Having Excessive Cost, Support Requirements, and/or Vulnerability (U)

(U) The last group of vehicles that should be disregarded in assessing the general potential of the Handbook-covered drones to tactical R&S missions are some of the Q-designated, manned vehicles that were converted to real-sized target drones. There are a number of reasons that these deserve little attention; cost, support requirements, and vulnerability are principal among these. For weapons-delivery missions, however, and perhaps for other typical hypothetical RPV missions, these drones would deserve considerably more attention. The Q-designated vehicles to be disregarded on this basis are listed in Table 6.

TABLE 6. DRONES UNSUITABLE FOR TACTICAL R&S MISSIONS DUE TO EXCESSIVE COST, SUPPORT REQUIREMENTS, AND/OR VULNERABILITY (U)

| Designation | Name | Weight | Remarks |
|---|---|---|---|
| QT-33A | Shooting Star | 15,000 lb | In active use |
| QF-9J | Cougar | 19,500 lb | Being replaced by QT-33A |
| QF-4B | Phantom II | 42,500 lb | Scheduled for Navy use in 1971 |
| QF-104A | Starfighter | 23,800 lb | In active use |
| QP-4B | | 65,000 lb | Out of use |

(U) The British and Australians have made similar conversions of manned aircraft to drone configurations. English Electric, in cooperation with Short Brothers and Harland, developed the target-drone version of the Canberra, designated the U.Mk. 10.

Such vehicles were in service at the Woomera test range. Fairey converted two versions of the RN Firefly strike fighter to drone configurations. These were designated the U.Mk.8 and the U.Mk.9. Flight Refuelling, Ltd., converted the Gloster Meteor fighter into drone configurations, designated U.Mk.15 and U.Mk.16.

(U) The QU-22B and the XQM-93A, manned aircraft derivatives, are not considered in the same category as the vehicles just discussed because they were developed specifically for electronic surveillance or related missions and because of their active, high-priority program status. The origin of these vehicles is discussed in the Handbook.

(U) There may be a number of nonmilitary, small, manned aircraft that would have some potential for tactical R&S drone adaptation. The appeal of low cost potential may be deceptive for this type of aircraft, however. The cost burden of adding a command-and-control system and mission/sensor equipment could raise the development and recurring cost to near that for an original development. The QU-22B and the XQM-93A are cases in point.

(U) The BD-5 manned aircraft, which will soon be available in a home-built kit form for a modest price, has been included in the Handbook as an example of a vehicle of this type that may be suitable for drone application. It is not possible to offer an assessment of its potential at this time; particularly in comparison to similar vehicles.

Drones Potentially Suitable for Tactical R&S Missions (U)

(U) The process of elimination described above leaves a number of drone systems which appear to have some potential for performing tactical R&S missions. These are listed in Table 7. The target vehicles included in this list may be assumed to have some potential for R&S adaptation, although, except for the BQM-34 (starting point for the 147 series), this is not a proven fact nor is it actively proposed for any of these vehicles.

(U) It is important to make the following observations regarding the vehicles in Table 7.

1. The MQM-58A (or the SD-2), the SD-3, the SD-5, and the Bikini are the only U. S. vehicles that were originally designed for combat surveillance. All of these are now defunct.

2. There are no U. S. vehicles in active use or with a formal development status for the combat surveillance role at this time.

3. There are very few active, U. S. conceptual or predevelopmental efforts in this class at this time.

4. The 154 is the only vehicle originally designed for the long-range surveillance role. The versatile 147 family began through modification of the BQM-34A, and should be viewed as restricted to strategic roles.

TABLE 7. VEHICLE BASE FOR RECONNAISSANCE AND SURVEILLANCE (U)

| Class of Vehicle | Proposed or Pre-development | In Development | In First Production | In Active Use | Development Dormant | Project Terminated | Out of Use |
|---|---|---|---|---|---|---|---|
| U.S. Target Vehicles – Supersonic | | | | BQM-34E (Firebee II) | | | |
| U.S. Target Vehicles – Subsonic | | | | BQM-34A (Firebee I) | Beech 1055 (or 1025 TJ) | | |
| | | | | MQM-36A | | | |
| | | | | MQM-61A (Cardinal) | | | |
| | | | | LTV-MK303A (see Jindivik MK3A) | | | |
| U.S. Reconnaissance and Surveillance Vehicles – Supersonic | | | | | | SD-4 (Swallow) | |
| U.S. Combat Surveillance Vehicles | NV-113 | DH-2E (Whirlymite) | | | | SD-3 | MQM-57B (Falconer) |
| | Owl | | | | | SD-5 | |
| | | | | | | | MQM-58A (Overseer) |
| | | | | | | | Bikini |
| U.S. Long-Range Surveillance Vehicles | | | | 147 Series | | | |
| | | | | 154 (Firefly) | | | |
| U.S. Test Platforms and Electronic Relay Platforms | | | | QH-50D (DASH) | | | |
| | | | | QU-22B (Pave Eagle) | | | |
| | | | | XQM-93A (Compass Dwell and Compass Cape) | | | |
| Foreign Target Vehicles – Subsonic | | Turana | | Jindivik MK3A | | | |
| Foreign Combat Surveillance Vehicles/Platforms | | Kiebitz (Tethered platform) | CL-89 | R.20 Meteor P 1/R | Epervier X-4 | | |
| | | | | | Aerodyne | | |
| | | | | | KAD | | |

5. The MQM-57B stems from the target drone MQM-36A. The Meteor P. 1/R is a reconnaissance version of the Meteor P. 1 which is closely related to the MQM-36A.

6. The R.20 also stems from a target vehicle, the CT.20.

7. The NV-113 is a proposed vehicle based on the MQM-74A target vehicle.

8. There has been only one project for a supersonic reconnaissance and surveillance drone; the SD-4. The project was unsuccessful.

9. The major innovation in the combat-surveillance vehicle class has come from the foreign developers. Unfortunately, several of these novel, purportedly advanced state-of-the-art, developments are lagging. Some foreign tethered-platform developments were not included in the Handbook because of the status of the developmental efforts. These are discussed later. Kiebitz is shown as developmental; although it has not made steady progress in development, the program has progressed better than most tethered-platform developments.

10. The Beech 1055 target vehicle is an outgrowth of the MQM-61A target vehicle. Reconnaissance potential has been suggested by Beech for this family, but such versions have not been developed.

11. The Australian Jindivik and the Turana target vehicles appear to have potential for R&S adaptation but there is no evidence that this has been pursued, to date.

12. The following set of vehicles are considered to be representative of new technology and growth potential in the battlefield and medium range surveillance class:

    CL-89
    NV-113
    DH-2E
    QH-50D
    Owl
    Kiebitz
    Jindivik
    Turana
    Epervier
    Aerodyne

13. The 147/154 vehicles represent unique capabilities. There is no comparable existing or growth capability in other drone vehicles. Current new developments (e.g., multimission, high-altitude, long-endurance, strategic-vehicle developments) promise additional capability. The

state of the art represented by these advanced strategic vehicles is not assessed specifically in this report. It is believed that because of the special character of these vehicles, emphasizing maximum range and extreme-altitude performance, the technology does not contribute significantly to tactical drones. The BQM-34A parent vehicle of the 147 family is adequately representative of the underlying technology base that may be pertinent to tactical drones.

14. The long-endurance, electronic-relay platforms (QU-22B and Compass Vehicles) are also in a separate technology class. Completely new developments are not being undertaken for this class of vehicle although there are improvement developments underway. There is a continuing requirement for more reliability and improved efficiency for vehicles in this mission class.

## RECOMMENDATIONS (U)

(U) Recommendations for future directions in the development, adaptation, and utilization of drone systems for tactical R&S missions can fall in two categories. One of these involves system/mission considerations, and the other involves specific technical developments on the drone vehicle.

### Systems/Mission Considerations (U)

(C) As used here, systems/mission considerations refer to the general problem of matching the R&S vehicle and its support equipment with the mission from the standpoints of cost, performance, and convenience. Basically this is the "user orientation" problem. Lacking detailed knowledge of the current or potential drone missions, it is difficult to make specific recommendations in this area. However, during the course of this program three topics have been identified which merit attention:

- coordination between flight-vehicle development and mission requirements
- relative merits of drones vs RPVs
- complexity of ground support systems.

#### Coordination Between Flight-Vehicle Development and Mission Requirements (U)

(C) The Army's recent history relative to drone development and utilization is of interest here. A brief synopsis of this history is given in Appendix C. It is significant to note that, having been the leader among the Services in the use of drones for surveillance and target-detection missions prior to 1964, the Army at that time abandoned its drones. Discussions with a number of Army Agencies* indicate that the reasons for this decision were more use-oriented than technical. That is, lack of vehicle, sensor, or other subsystem performance, per se, was not the major problem. Rather, it appears that the problems were primarily use-oriented, indicating that inappropriate choices were made in developing the systems, mission constraints were not thoroughly analyzed, and the value of drones relative to other mission alternatives was not completely evaluated. Basically it appears that there has been too much emphasis on "drone work for drone's sake", and too little consideration of such questions as:

- What are the missions which cannot be done without drones or which are too risky and/or expensive without drones?
- What must be the total physical, operational, and cost characteristics of a drone system for it to be best-suited for the mission?
- What is the price of compromising these characteristics?
- What drone-system characteristics must be avoided if the drone is to be competitive or superior to alternative vehicles/methods?

Strong attention should be given to these questions in delineating future drone-development activities and goals.

## Relative Merits of Drones vs RPVs (U)

(C) The competition between drones and manned aircraft should not be underestimated. The current activity and emphasis on RPVs, as opposed to drones, is leading toward the development of capabilities and mission roles that cannot be challenged by manned aircraft.** When the remote pilot or operator is able to observe or to orient sensors and designators, limited very little by the fact that he is not actually in the cockpit, then a sufficiently unique capability will exist for viable, general-purpose, unmanned, tactical, surveillance-and-target-detection vehicles. It is believed that with this capability on the horizon, every other tactical R&S drone development, except perhaps those based essentially on a philosophy of expendability, will be stopgap at best. Strangely, RPV planning has emphasized other roles, such as defense suppression, weapons delivery, strike (penetration aids), and air-to-air combat. In the R&S battlefield-type drones of the current state of the art, the observation portion of the mission trajectory is usually preprogrammed. Thus, the collection of information cannot be affected at all by what is being observed. In some cases, the path or ground track of the vehicle is actively recorded on a plotter board and a command mode is in effect during the observation phase of the mission. However, there are no vehicles

*These include the Assistant Chief of Staff for Force Development (ACSFOR), the Assistant Chief of Staff for Intelligence (ACSI), the Assistant Chief of Staff for Communications-Electronics (ACSC-E), Headquarters of Combat Development Command (CDC), and the Advance Materiel Concepts Agency (AMCA).

**The terminology RPV in this context refers to vehicles which generally require the same inputs from and provide the same responses to a remotely located pilot as would be required from or received by a pilot actually in the aircraft.

equipped with sensors and data links for a factual real-time capability; accordingly, there is effectively no feedback nor basis for refining the mission phase while it is in progress. R&S drones for tactical operations have never had the policy support that is found today for the multimission RPV. Thus, even the most advanced drones lack the capabi''ties for real-time data interpretation and active operator participation that is now sought for the typical RPV. It seems clear that the RPV will lead the way in this mission area in the future and that the canned, predetermined, picture taking, fire-it-and wait type drone will be drastically deemphasized for tactical surveillance. For medium-range and strategic missions, the emphasis is more likely to be on determining the longer-term trends in enemy position and strength, the character of his activity, and other quasi-static indicators. Thus, reaction will be less important and different rules may apply. Navigation accuracy requirements and range may dictate a highly sophisticated, self-contained system, as with the 147/154 vehicles. If the human is not required for the functions of integration, decision and reaction, then the RPV principles become less pertinent.

(U) On this basis, it is recommended that strong attention be given to RPVs for tactical R&S missions. Admittedly a cost penalty may be imposed in utilizing an RPV rather than a drone. However, for many missions the advantages may be well worth the cost.

Complexity of Ground-Support Systems (U)

(U) The complexity of ground-support requirements has been a major drawback in tactical-surveillance drone systems. Some of the systems may have inherited the complexity and variety of equipment that was associated with target-drone applications, having entirely different constraints on reaction time, space, site preparedness, mobility, and retrieval. Some of the elementary systems, such as the Bikini, emphasized keeping the ground-support equipment to a minimum. The Bikini was considered a two-man system. The Firebee I, according to Air Force experience at Tyndall AFB, requires 40 men to launch, maintain and recover one vehicle. Thus, the Bikini was an exception to the norm. The system, including two drones, fit in a jeep-drawn M-100 trailer and was launched from a trailer-mounted pneumatic catapult. Of course, its wing span was only 8 feet, and its weight 60 pounds. A few other drone systems have been kept to a launcher and one major vehicle in the ground system.

(U) The following figures show that the ground-equipment requirements for many of the R&S drone systems have been permitted to become more extensive than is reasonable for the nature of their mission and to tactical environment. Unfortunately, some of the newer system concepts have this fault.

(U) The MQM-58A, the principal U. S. combat surveillance-drone development, required many support vehicles. Figure 1 shows the surprising variety of vehicle allocations "required" to support this system. The MQM-58A was a 1-hour-endurance, 1,400-lb, 300-knot airplane.

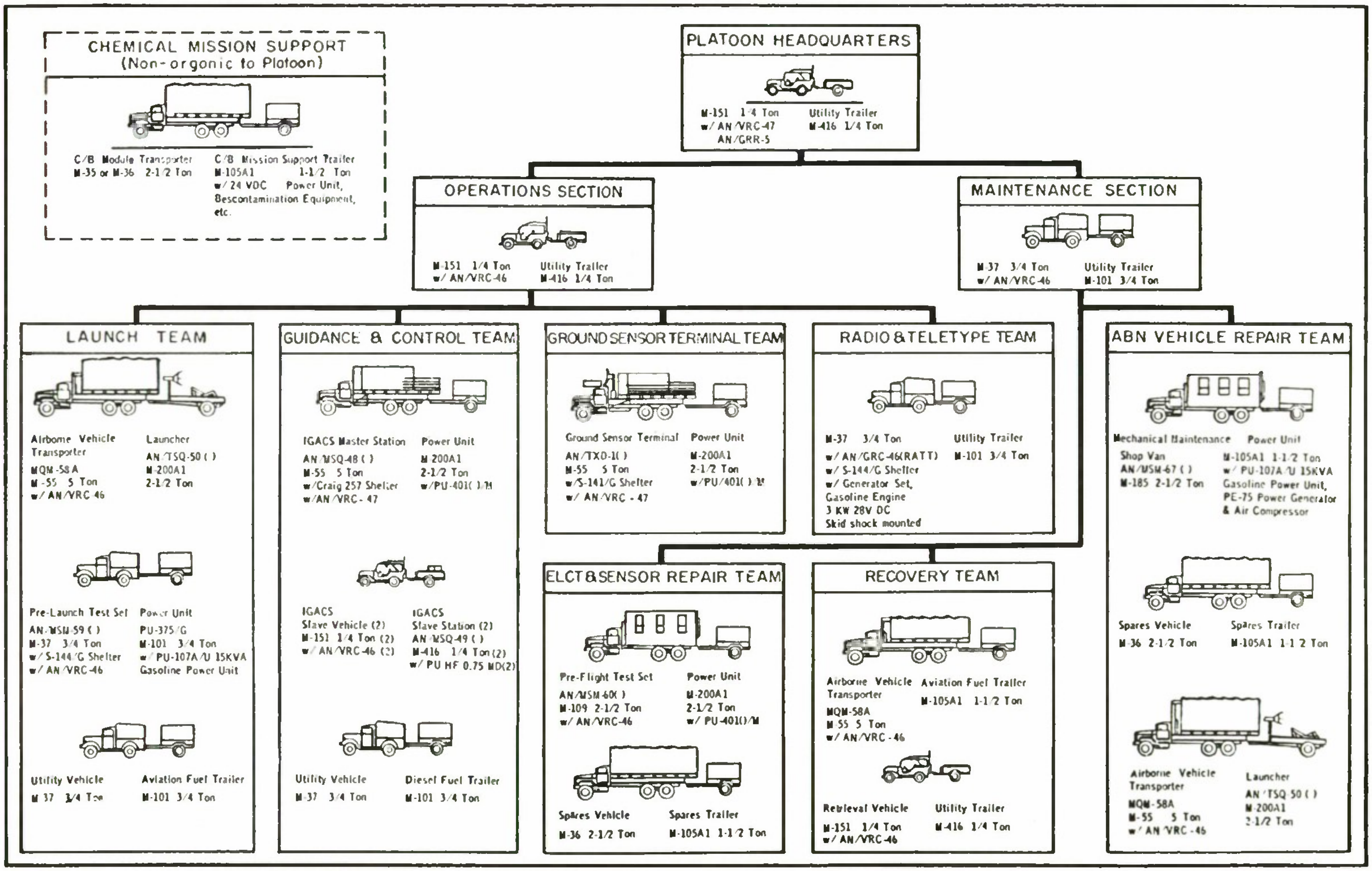


FIGURE 1. MGM-58A VEHICLE ALLOCATIONS (U)

(C) Figure 2 shows an emplacement for the typical R.20 (Nord) mission. The R.20 is still active, although it is doubtful that it has ever been used except under ideal training and testing conditions. The variety of vehicles is again evident (notice the duplicate command-guidance units). Parachute recovery is often oversimplified as it is in this sketch. No retrieval equipment is shown. Figures 3 and 4, showing retrieval of the Cardinal, speak for themselves on this point. It can be easily imagined that retrieval is a time consuming and delicate operation.

(C) Figure 5 deals with the KAD, the future of which is uncertain. KAD includes the revolutionary rotating tail feature, presumably to minimize the problems of recovery. Still, it has a tremendous burden of ground equipment. Of course KAD would have a moderate range and this might be a reasonable, semipermanent installation.

(C) The CL-89 installation is similarly complex. The basic equipment list for the CL-89 system includes the drone, sensor system, launcher vehicle, homing-beacon equipment, photo-processing-and-interpretation vehicle, mission-planning vehicle, recovery-area vehicle, repair vehicle plus electrical and pneumatic power, supply trailer, and replenishment vehicle plus trailer. It was mentioned earlier that the cost of a complete CL-89 system was approximately $2 million. The drone flight-system cost is estimated at $60,000; about 3 percent of the total.

(U) Air-launch-and-recovery modes and an airborne command post can eliminate the ground requirements. This is not the typical procedure, however, for the tactical R&S drone systems. Problems of logistics and coordination arise when this mode is used and these problems reduce the system responsiveness and the control that ground forces have over the operation.

(C) An interesting concept, which is currently being pursued, is the NV-113 drone, to be air launched in support of fighter/bomber missions. Due to the relatively small size, the launch aircraft could carry up to six of these drones.

(C) Mid-air recovery remains less than an ideal solution to the recovery problem. The USAF MARS system is used for the Firebees and their derivatives and is the only fully standardized system in use. It is constantly undergoing modifications and reappraisal. Apparently, the logistics requirements are diverse and costly. It has been estimated that half of the operations cost is for mid-air recovery of these drones. Also, the recovery success has averaged only about 75 percent over the past 5-6 years, although it has been much better in 1970 and 1971.

(C) From every viewpoint, it would be highly desirable if parachute recovery in any form could be eliminated entirely, particularly for the short-range drones. This would require either the development and perfection of a revolutionary concept like KAD, the exclusive use of helicopter drones, or normal field landing. The Jindivik target drone uses normal field landing, but it is an exception. Of course, the requirement for a prepared field would usually be incompatible with tactical environments, and this is not a likely choice for battlefield surveillance drones.

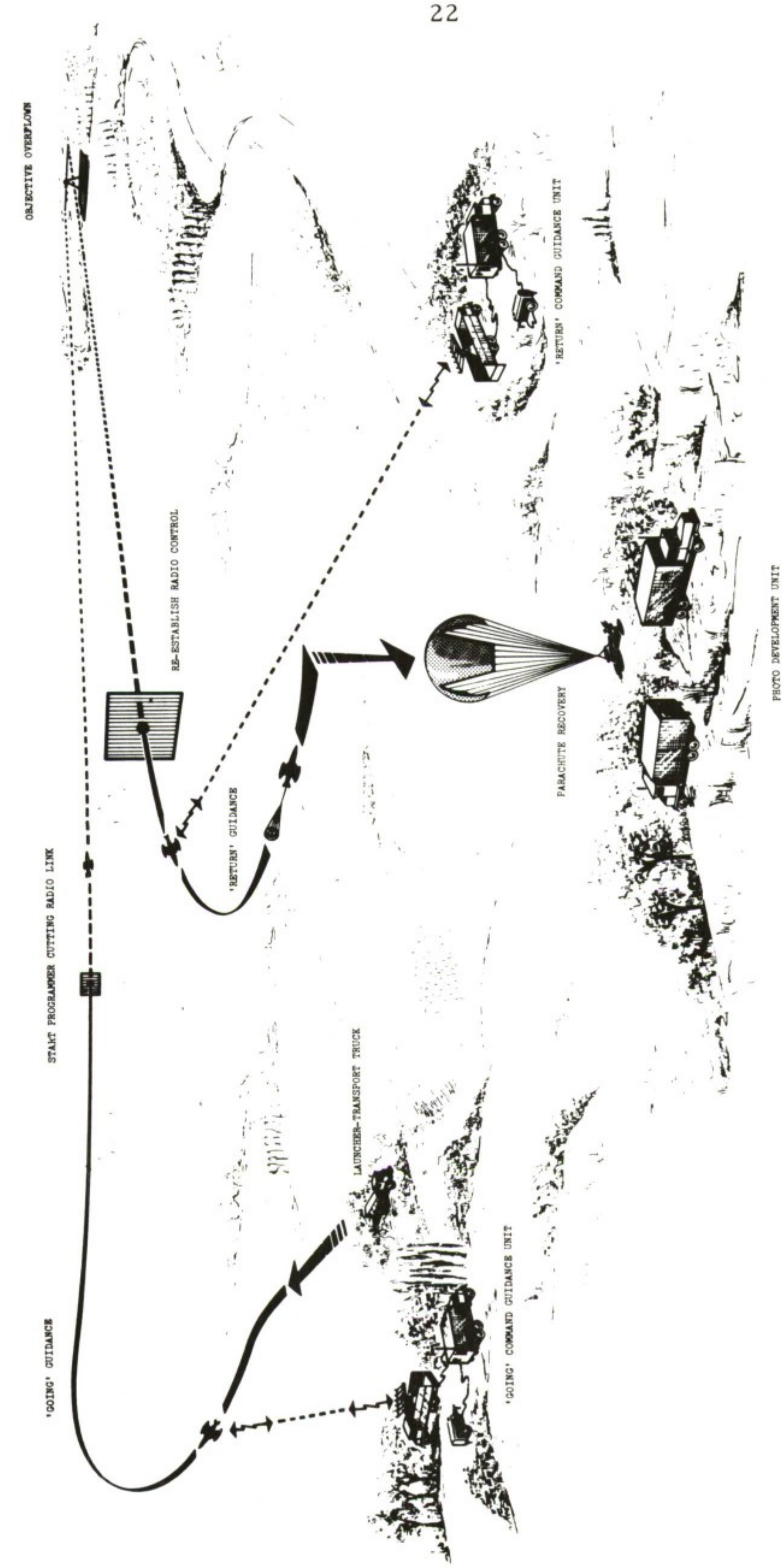


FIGURE 2. TYPICAL R.20 DRONE MISSION (U)

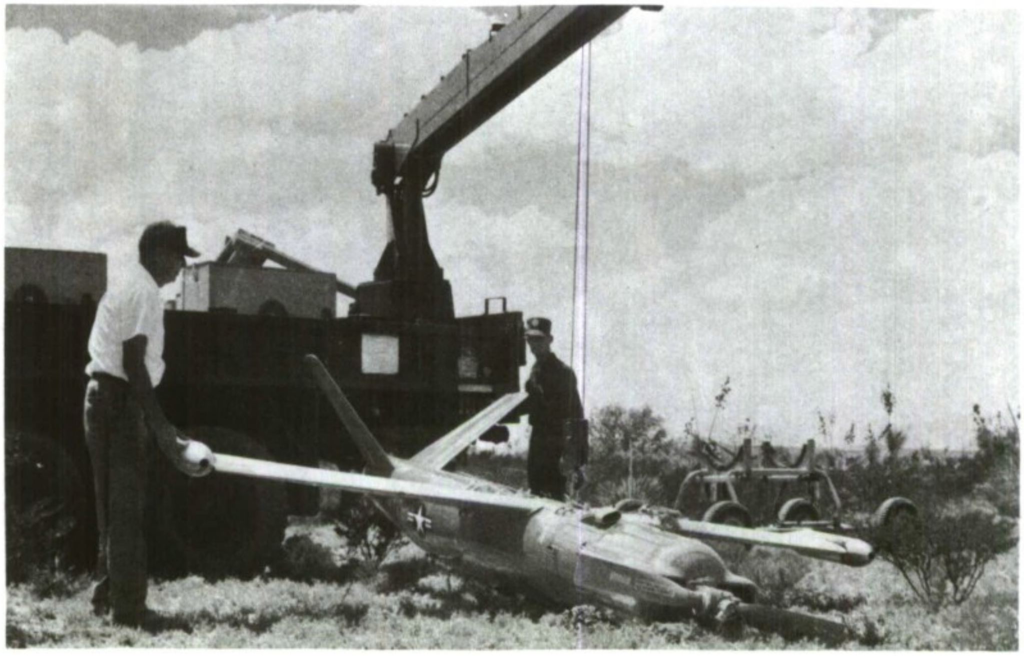

FIGURE 3. CARDINAL LIFTED FROM DESERT FLOOR (U)

FIGURE 4. CARDINAL TRANSPORT DOLLY (U)

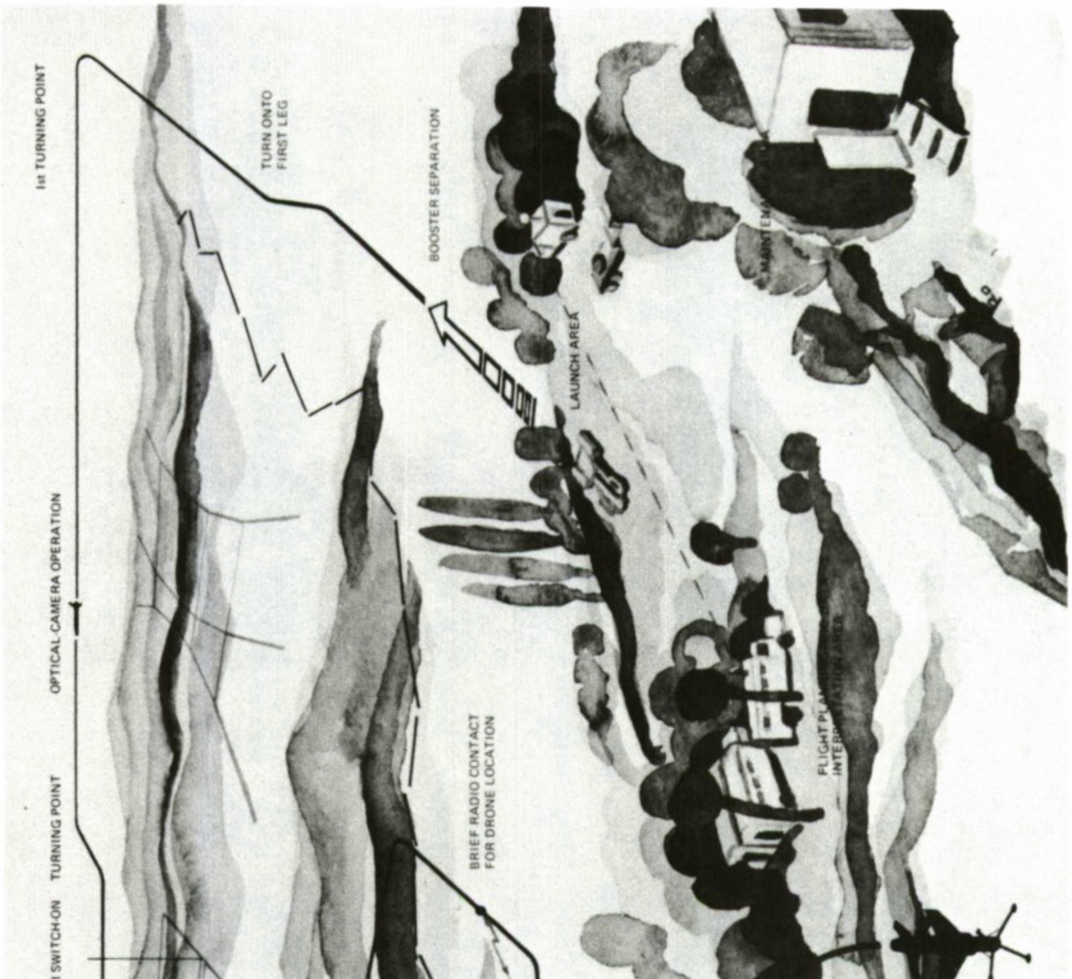


FIGURE 5. TYPICAL KAD DRONE MISSION (U)

(U) Overall it would appear that much stronger attention should be given to the potential merits of helicopter-type drones. Their assets in the launch-and-recovery phases, not to mention hover capability, could outweigh other limitations, notably speed, endurance, payload (if they are to be reasonably small), additional control difficulties, and relatively high cost.

## Specific Technical Developments (U)

(U) In spite of major systems concept problems, as discussed previously, there is some need for improvements and technical refinements in the critical subelements of drone systems. However, it is doubtful if such improvements can be the key to qualitatively better systems in the foreseeable future and without major innovation in the troublesome areas of recovery, ground-support requirements, command and control, and data-processing elements. Moreover, it is believed that technical refinements in such areas as propulsion, structures and airframe, navigation-and-guidance systems, command/control systems, and mission sensors are secondary to better analysis of mission requirements and the exercise of more stringent constraints in the process of vehicle definition. Obviously, an improved state of the art would give more latitude and versatility in this process, and it is important to pursue the opportunities that exist. The following technical objectives and recommendations pertain to subelement refinements that would benefit R&S drone systems.

### Navigation/Control/Sensor Weight Constraints (U)

(U) The ratio of payload to gross weight invariably suffers as the size of an aircraft is reduced. For R&S drones that have actually been built, the ratio is typically about 10-15 percent, with a few reaching 20 percent. The weight of the airborne navigation-and-control system in a drone is potentially such a large fraction of the gross weight that in a technological sense, if not in a systems sense, it should be considered as part of the payload.

(U) It is useful to note the effect of these approximate constraints on either the minimum gross weight of drones or on the type and sophistication of the sensors and guidance-and-control (G&C) equipment that they can accommodate.

(C) The following are some minimum weights for several important types of sensors:

| | |
|---|---|
| Frame Cameras | 80 lb |
| Mini-panoramic Cameras | 15 lb |
| Infrared Raster Scanners | 150 lb |
| Laser Line Scanners | 150 lb |
| Tactical Daylight TV Systems | 35 lb (100 lb typical) |
| Low Light Level TV Systems | 50 lb (50-400 lb range) |

(U) Table 8, from the Rand Drone Cost Study, includes typical weights for drone guidance/navigation and control systems.

TABLE 8. CHARACTERISTICS AND ACQUISITION COSTS OF REPRESENTATIVE DRONE GUIDANCE AND NAVIGATION SYSTEMS (U)

| System | Potential Accuracy (Error) | Weight (lb) | Cost ($ Thousands) |
|---|---|---|---|
| Autopilot | | | |
| Autopilot | 3 to 5 percent distance flown | 80 | 60 |
| Autopilot-doppler | 1 to 3 percent distance flown | 100 | 80 |
| Autopilot-Loran | 500 ft (straight flight only) | 100 | 90 |
| Autopilot-doppler/Loran | <3 percent distance flown | 100 | 110 |
| Inertial | | | |
| Pure inertial | 1.5 to 2 n mi/hr | 60 | 70-100 |
| Doppler-inertial | 0.5 to 1 n mi/hr | 100 | 225-275 |
| Doppler-inertial Loran | <1 n mi/hr | 135 | 275-325 |

(U) The combination of a preprogrammer/autopilot system and a minipanoramic camera would constitute a payload of approximately 100 lb. This in turn would imply a vehicle gross weight of 700-1,000 lb minimum.

(U) The Owl vehicle is in this weight range and it has an exceptionally good payload fraction, probably due to the use of advanced structures and Wankle engine. It is intended that it would carry an autopilot-Loran system and TV equipment. Its 200-lb payload allocation in addition to G&C equipment would permit flexibility. The CL-89, the NV-113, the Epervier, and the Meteor P. 1/R are in a lower weight range, from 300-600 lb. A definite price in sophistication has been paid to keep them in that size and weight range, and their payload versatility is limited.

(U) The conclusion of these observations is that new developments to minimize the weight of advanced sensors and navigation/control systems will have an impact on tactical R&S drones, but it will definitely be of the diminishing returns type. More would be gained by improved vehicle concepts and support concepts for a 700-1,000 lb vehicle using the advanced state of the art that is already available in these critical subelements. The 1,000-3,000-lb weight-class drone would, of course, give considerably more flexibility with respect to sensors and other subsystems, but the use-oriented problems increase rapidly with the weight. It is probable that potential drone users could benefit most in learning to use the newest state of the art in navigation and control systems and mission sensors by drawing on RPV developments and the advanced tactical-missile concepts such as TV and laser guidance.

Drone Engine Objectives (U)

(U) A review of the Handbook will show that the selection of drone engines is limited. Many of the drones use essentially the same engine. Only a few of the engines were developed primarily for drone use. Unfortunately, the low horsepower and thrust class appropriate for drone applications is one in which there have been few high priority developments and as a result the engines are not as completely engineered as for typical developments in higher power classes. In some cases, even the amateur type of developer has been able to enter the field. The Dreher Baby Mamba turbojet is an example. This 25-lb engine can develop 45-lb thrust (continuous). Several similarly rudimentary reciprocating engines are being developed for the self-launched sailplane which is growing in popularity. Some may be suitable for drone applications. Extremely small engines almost invariably suffer from poor efficiencies and this is difficult to change by additional engineering.

(U) It is believed that the most significant contribution to drone propulsion will come through efforts aimed at engine cost minimization. The tactical reconnaissance and surveillance drone can stand the compromises of relatively poor efficiency, but there is a need for the engine cost to be more compatible with the limited expected life of such drones. The performance requirements for strategic R&S drones, particularly the high-altitude versions, are far more demanding, but they are relatively large vehicles and some sophistication is possible with the engines. The Teledyne Continental J69-T-29 and the J100-CA-100, are relatively sophisticated engines in the 1,000-2,000-lb-thrust class. Still, there is the need for lower cost.

(C) The on-going ordnance engine programs being conducted by the Navy, NASA, and the USAF have as a prime goal to simply reduce engine cost by production innovation and by designing for lifetimes compatible with application. Developments from these programs and such items as the Harpoon engine (an expendable turbojet) should make a direct contribution to the engine state of the art that is pertinent to drones. A goal of $8-10 per pound of thrust is the target for these developments. The smaller engines are now in the $20-100 per pound of thrust class.

(U) Some interest has been expressed in pulse jets for drone applications because of the low cost potential; perhaps $3 per pound of thrust. Except for the CT.10, only one other drone development is known to have been undertaken based on a pulse-jet system. This was the Aviolanda AT-21 (Netherlands) surveillance-and-target drone, which was largely unsuccessful (Circa 1960). It was not covered in the Handbook because of this status. It would have used a Snecma Type AS-11 (150-lb thrust) pulse jet, which is apparently no longer an active development product.

(U) The early Epervier vehicle used a Wankel type engine as does the current Owl concept. The attraction is the superior power-to-weight ratio relative to reciprocating piston engines. The use of Wankels still represents an innovative stretch because of the uncertainties of a good performance match, reliability, and cost characteristics. More experience will be required before a good appraisal can be made of their usefulness for drone applications.

(U) Ramjets and rockets are believed to be of limited value for future R&S drone developments.

(U) Turboshaft engines have had little consideration for conventional aircraft drones. Again, there is a lack of variety in the required power class and costs are high.

(C) Quiet engines have not been emphasized in drone developments to date. The Owl does aim for a reduced noise signature, but apparently no special noise constraints were applied to the earlier tactical R&S drone developments. The Advanced Development Objective cited earlier did specify minimum noise. More constraints on engine noise would be expected in any future developments, but small-engine developers are not likely to be very responsive to this challenge without specific support.

(U) Additional views on the drone engine state of the art and needs are found in the ARPA sponsored Rand Study on "Cost and Performance of Reconnaissance Drones" (U), March, 1971.

## Structures and Airframes (U)

(U) It is informative to consider some of the major conventional tactical R&S drones and related target types with respect to the ratio of their empty weight to the takeoff (T.O.) weight including boosters. Some typical examples are given in Table 9.

TABLE 9. WEIGHT BREAKDOWN FOR SOME TYPICAL DRONES (U)

| Drone | Empty Weight, lb | Max. T.O. Weight, lb | Ratio of Empty to T.O. Weight, % |
|---|---|---|---|
| MQM-58A | 886 | 1,400 | 63 |
| BQM-34A | 1,500 | 2,500 | 60 |
| MQM-39A | 457 | 727 | 63 |
| MQM-57A | 354 | 448 | 79 |
| MQM-74A | 250 | 408 | 61 |
| NV-113 | 327 | 594 | 55 |
| Epervier X-4 | 213 | 306 | 70 |
| CL-89 | 172 | 343 | 50 |
| R.20 | 1,463 | 2,420 | 60 |
| Bikini | 58 | 60 | 97 |
| QH-50D | 1,035 | 2,550 | 40 |
| DH-2E | 476 | 650 | 73 |

(U) Most of the T.O. weights include a RATO booster; an exception is the NV-113 which is air launched. Payload typically constitutes 10-15 points of the ratio, which averages about 60 percent for the conventional aircraft types. Bikini and the helicopter exceptions are shown for comparison only. The booster weights for these sample vehicles will be found to be slightly less than 10 percent of the gross weight, thus approximately 10 more points are made up by the boosters. This begins to suggest that the basic airframe, power supplies, recovery equipment, propulsion system, and control mechanisms are only about 35 percent of the T.O. maximum weight. This indicates that these drones are considerably better in this regard than typical manned aircraft (including the larger transport aircraft), since for the latter the basic airframe alone comprises roughly 35 percent of the gross weight. This situation may change appreciably for future RPV developments since the basic reason that these drones have such a low structural factor is that they are designed for low g-loading. They also lack such refinements as flaps, landing gear, and pressure systems. This indicates that the airframe is not a particularly profitable target for weight reductions, for this style of drone; but, it will be for high-g RPVs. However, lower safety margins could be used to keep down the structural weights for the high-g RPVs.

(U) Tactical R&S drone airframes are generally based on conventional aluminum technology. There is little basis to consider changes toward advanced high strength-to-weight ratio materials for this class of drones, particularly since supersonic types do not seem to have a viable mission role that would justify the cost and complexity. The same applies to the advanced composites. A proper emphasis would be upon the plastics and plastic/paper materials with an aim toward significant cost reduction, ultimately contributing to the possibility of expendable vehicles. However, these lower strength materials usually lead to weight increases in most airframe applications.

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APPENDIX A

<u>SUMMARY OF VISITS AND CONTACTS</u> (U)

# APPENDIX A

## SUMMARY OF VISITS AND CONTACTS (U)

(U) A broad-based information collection effort was undertaken in connection with this survey. Both U. S. and foreign manufacturers were visited as well as Department of Defense and Service agencies. Many industrial organizations that were expected to have only a minor role in drone development were contacted by letter.

(U) Table A-I is a summary of these visits and contacts.

TABLE A-1. A SUMMARY OF VISITS/CONTACTS IN CONJUNCTION WITH SURVEY OF DRONE AIRCRAFT SYSTEMS (U)

| General Categories of Organizations Visited/ Contacted | Organization | Location | Major Subjects of Discussion |
|---|---|---|---|
| Military Services (Visited) | Department of Defense | | |
| | Office of the Director of Defense Research and Engineering | Washington, D. C. | Area Coordination Paper (ACP) on aerial surveillance systems |
| | Advanced Research Projects Agency | Washington, D. C. | ARPA-sponsored research |
| | Department of the Army | | |
| | Office of the Assistant Chief of Staff for Communications Electronics | Washington, D. C. | AN/USD drone systems QMDO for UASS |
| | Office of the Assistant Chief of Staff for Force Development | Washington, D. C. | TARS 75<br>STANO study |
| | Office of the Assistant Chief of Staff for Intelligence | Washington, D. C. | Aerial surveillance requirements TARS 75 |
| | Advanced Materiel Concepts Agency | Alexandria, Va. | Aerial surveillance requirements ELTAS |
| | Army Security Agency | Arlington, Va. | Aerial surveillance requirements |
| | Department of the Navy | | |
| | Headquarters, USMC | Washington, D. C. | Bikini drone<br>Drone aircraft survey |
| | Naval Research Laboratory | Washington, D. C. | Drone aircraft and airborne sensors surveys |
| | Naval Weapons Center | China Lake, Calif. | BQM-34A drone<br>Drone aircraft control systems<br>Drone aircraft QT-33A, QF-9J, and QF-4B<br>HIPA's design studies |
| | Department of the Air Force | | |
| | Office of the Deputy Chief of Staff for R & D | Washington, D. C. | 147 and 154 series drones<br>QU-22 A/B drone<br>German and Italian drones |
| | Office of Drone Management, Aeronautical Systems Division | Wright-Patterson AFB, Ohio | 147 and 154 series drones<br>L450F drone program |
| | Aeronautical Systems Division Teledyne-Ryan | San Diego, Calif. | 147 and 154 series drones<br>BQM-34 A/E drones |
| Industry (Visited) | Goodyear Aerospace Corporation | Akron, Ohio | OWL drone |
| | Teledyne-Ryan Aeronautical | San Diego, Calif. | 147 series drones; 154 drone; BQM-34E drone |
| | Beech Aircraft Corporation | Wichita, Kansas | AQM-37 target drone; SCAD; Beech Model 1019; Beech Model 1025 |

TABLE A-1. (Continued) (U)

| General Categories of Organizations Visited/ Contacted | Organization | Location | Major Subjects of Discussion |
|---|---|---|---|
| Industry (Visited) (Cont'd) | Atlantic Research Corporation | Costa Mesta, Calif. | High speed glider; Samson II; Maxi-decoy; Century decoy; Fiber fighter TOW targets; Full-size maneuvering target; Drone concept of the full-size maneuvering target |
| | Northrop-Ventura Corporation | Newbury Park, Calif. | MQM-74A target drone; Q-4 and Q-4B target drone; SCAD; NV-113 (rcn version of the -74A); Advance drone analysis program; Drone mission studies |
| | Del Mar Engineering Labs. | Los Angeles, Calif. | Whirlymite drone helicopter |
| Military Services (Contacted) | Department of the Army<br>Institute of Intelligence and Control Systems, Combat Developments Command Hq. | Ft. Belvoir, Va. | STANO Resource Management study report information |
| | Department of the Air Force<br>Special Assistant for Sensor Exploitation, Office of the Vice Chief of Staff | Washington, D. C. | Information on aerial surveillance requirements |
| | Air Force Systems Command | Andrews AFB | Drone information |
| | Air Force Armament Lab. | Eglin AFB | Limited information on development activities |
| Industry (Contacted) | Aerostructures, Inc. | Menlo Park, Calif. | Not active |
| | Air Craft Marine Engineering Corp. | Calabasas, Calif. | Information received |
| | Aircraft Technical Service, Inc. | Van Nuys, Calif. | Not active |
| | Bede Aircraft, Inc. | Cleveland, Ohio | Information received |
| | Cardion Electronic | Woodbury, New York | Not active |
| | Chrysler Corporation | Detroit, Michigan | No response |
| | EFMC Corporation | Compton, Calif. | No response |
| | Fairchild Republic | Long Island, N. Y. | Information received |
| | F & M Systems Company | Dallas, Texas | No response |
| | Gyrodyne Company of America, Inc. | Long Island, N. Y. | Information received |
| | Hayes International Corp. | Birmingham, Ala. | Not active |
| | Hughes Aircraft Corp. | Culver City, Calif. | No response |
| | Kaman Aerospace Corp. | Bloomfield, Conn. | No response |
| | Lockheed Aircraft Corp. | Burbank, Calif. | Limited information received |

TABLE A-1. (Continued) (U)

| General Categories of Organizations Visited/ Contacted | Organization | Location | Major Subjects of Discussion |
|---|---|---|---|
| Industry (Contacted) (Cont'd) | LTV Aerospace Corporation | Dallas, Texas | Information received |
| | Maxwell Electrics Corporation | Great River, N. Y. | No response |
| | North American Rockwell | Columbus, Ohio<br>ElSegundo, Calif. | Information received |
| | Northrop Corporation | Beverly Hills, Calif. | Information received |
| | Owens-Corning Fiberglass Corp. | Toledo, Ohio | Information received |
| | Piasecki Aircraft Corp. | Philadelphia, Pa. | No response |
| | The Synthetics Company | Dallas, Texas | No relevant activity |
| | TRW Systems Group | Redondo Beach, Calif. | No relevant activity |
| | San Diego Engineering, Inc. | San Diego, Calif. | Information received |
| | Service Technology Corp. | Dallas, Texas | No relevant activity |
| Foreign Agencies (Visited) | Canadian Defense Liaison Office | Washington, D. C. | Canadian drone aircraft survey CL-89 and AN/USD-501 drones |
| | German Federal Ministry of Defense | Bonn, Germany | German drone aircraft systems |
| | Dornier AG | Friedrichshafen, Germany | KAD drone<br>Aerodyne drone<br>Kiebitz drone |
| | Société National Industrielle Aerospatiale (SNIAS) | Paris, France | CT. 20 target drone<br>R. 20 drone |

APPENDIX B

FOREIGN DEVELOPMENT ACTIVITIES (U)

# APPENDIX B

## FOREIGN DEVELOPMENTS (U)

(U) During the initial portion of this research project, Battelle personnel visited the following foreign agencies on the subject of their development of drone aircraft and tethered aerial systems:

- The Société National Industrielle Aerospatiale (SNIAS)
- The German Federal Ministry of Defense
- Dornier
- The Canadian Defense Liaison Office

No visit was made to the Italian Meteor, SA. These visits were useful in terms of obtaining a first-hand insight into the attitudes and activities of major foreign developers. In general, the classified foreign reports cited in this Appendix were obtained through official channels and were used in the preparation of the Handbook.

### Visit to the French Société Nationale Industrielle Aerospatiale (U)

(U) A visit was made to the Division des Engins Tactiques (Division of Tactical Missiles), Société National Industrielle Aerospatiale (SNIAS) near Paris (2 á 18, Rue Béranger, 92 Chatillon-sous-Bagneux, B. P. 36). The purpose of the visit was to collect all available information on the French development of drone aircraft and tethered aerial systems. The point of contact at SNIAS was M. Guillemin, who was joined by an assistant, M. Berroir, during the course of the meeting. M. Guillemin is the Chief of the Target and Surveillance Drone Group within the Tactical Missiles Division.

(C) SNIAS is the Government-controlled successor to Nord-Aviation. Although SNIAS claims to be a private corporation, the Government owns a major portion of the stock and has personnel on the Board of Governors of SNIAS. There are no other French competitors of SNIAS in the drone aircraft field. Foreign customers of SNIAS include Sweden, Italy, and Greece. A surface-to-surface (coast-to-ship) version of the CT.20 (with a homing system and warhead and a range of 120 km has been produced for the Swedish Navy. This system (RB.08), however, does not have remote control.

(U) Work on target-and-surveillance drone-aircraft systems, which began at Nord-Aviation (now SNIAS) in 1947, led to the development and production of the following drones:

- CT.10 – A low-speed, low-altitude pulse jet drone.

- CT.20 – A turbojet-powered, subsonic drone.

- CT.41 – A Mach-2, ramjet-powered drone (see the PQM-56A).

All of the foregoing systems were designed as target systems. Pertinent information with regard to their characteristics is presented in the Handbook.

(U) The version of the CT.20 now being produced is the fourth, but there are relatively few changes from the first. Approximately 2,000 CT.20s have been produced to date and SNIAS is planning to continue production until 1975.

(C) The R.20 Battlefield Surveillance System was derived from the CT.20 target drone. A description of the R.20 system is contained in the Handbook. As is indicated, the R.20 is currently designed for daylight photographic reconnaissance, but the system will be modified by the end of 197? to permit night IR surveillance and real-time data transmission and display. Although the R.20 is not currently in production, one regiment of the French Army has been equipped with the system for the past 5 years. The drone has been designed for high-threat environments and appropriate vulnerability studies of the system have been made.

(U) In response to questions on the development of tethered aerial systems (like Dornier's KIEBITZ), M. Guilleman advised Battelle personnel that a stabilized, turbojet aerial system called ORPHEE was being developed by SNIAS about 5 years ago. Development was conducted in conjunction with Dornier's work on the KIEBITZ, but the program was subsequently terminated.

## Visit to the German Federal Ministry of Defense (FMOD) (U)

(U) A visit with Herr J. Weiss of the FMOD in Bonn on April 16, 1971, indicated that there are only three drone aircraft and tethered aerial systems under development for the Federal Ministry of Defense and all of these are being developed by Dornier. Obviously, Dornier has a number of sub-contractors for the three systems, but the FMOD recognizes Dornier as the only German firm currently developing these systems. All work on these systems is being conducted at the Dornier plant in Friedrichschafen on the Boden See (Lake Constance) in Southern Germany. The three systems discussed with H. J. Weiss are as follows:

### KAD (U)

(U) KAD is a sophisticated, medium-range, Army Corps-level, all-weather-reconnaissance, drone-aircraft system under development for the German Army. H. J. Weiss provided a copy of the latest progress report on the KAD system and a copy of a detailed report on KAD was subsequently received through official channels. During the discussion of the KAD system, H. J. Weiss indicated that FMOD has invested ~ $70 million DM (~ $21 million) in the development of the system to date, but that the overall system is only about 35 percent developed. FMOD did not fund the development of the KAD beyond the end of FY 1971. The U. S. Air Force appears to have some interest in the KAD system components. Meanwhile, the German Army is currently using the Canadian CL-89 as a division-level, drone-aircraft surveillance system.

AERODYNE (U)

(U) AERODYNE is an unusual, short-range, drone aircraft system which currently exists only as a wind tunnel test model. An experimental model was to have been flown for the first time in October, 1971. According to H. J. Weiss, the system will ultimately be developed as a surveillance and target-spotting vehicle for artillery. However, it will require an improved engine. The system will be capable of hovering or traveling at a Mach 0.9 velocity. The AERODYNE Corporation of U. S. A. (primarily Dr. Lippisch).

KIEBITZ (U)

(U) KIEBITZ is a mobile, tethered aerial system which was developed on the basis of German experimentation with a reaction-driven one-man helicopter. Inquiries have been received from a number of the NATO countries (and Sweden) with regard to the KIEBITZ system, and it has been demonstrated for them. There may be several versions of the KIEBITZ system, depending upon the altitude and payload requirements. At the present time, the system will carry a payload of 100 Kg to 300 meters. A new version may carry 550 kg to 1000 meters. The Dornier program manager for KIEBITZ is Herr Kanna Müller.

(U) In conjuntion with the visit to the German FMOD, contact was made with Col. Hugh Mitchell, USAF R&D Liaison Officer with the U. S. Embassy in Bonn. Col. Mitchell maintains regular liaison with the FMOD for the purpose of exchanging RDT&E information of interest to the U. S. and the Federal Republic of Germany (FRG). Hopefully, some RDT&E of mutual interest can be performed on a cooperative basis, but the projects should not be large because the FMOD cannot accommodate major U. S.-FRG RDT&E efforts. The joint development of drone aircraft or tethered aerial systems is considered to be a suitable area for collaboration.

Visit to Dornier A. G. (U)

(U) The Dornier plant responsible for the development of drone aircraft and tethered aerial systems is located a short distance from Friedrichshafen, Germany (on the Boden See). The host for the visit on April 19, 1971, was the Director of the plant, Dipl.-Ing. Hans Kinsler. He was joined successively by Herr Kanna Müller (Director of drone helicopter/KIEBITZ developments) and Dr.-Ing. Wolfgang Melzer (Director of advanced aerial systems such as the AERODYNE).

(U) No additional information (above and beyond that procured from H. J. Weiss in the German FMOD and Col. H. Mitchell in the U. S. Embassy, Bonn) was obtained on the KAD medium-range, all-weather-reconnaissance, drone-aircraft system. Work on this system has been terminated by Dornier.

(U) With respect to the KIEBITZ tethered aerial system, Kanna Müller advised the Battelle personnel that the definition phase of the program will end in June 1971 and that operational tests will then be initiated. Demonstrations will be conducted for NATO countries in October, 1971. Development and production of a standard model of the KIEBITZ system is planned by 1975.

## Visit to the Canadian Defense Liaison Office (U)

(U) Mr. J. G. Price of the Canadian Defense Liaison Office in Washington, D. C., discussed three drone systems developed by Canadian manufacturers. These were the Canadair CL-89 (AN/USD-501), the Canadair CL-227, and the Canadian Westinghouse PERISCOPTER. All of these systems were conceived as R&S drones and were not converted target drones.

### CL-89 (U)

(U) The CL-89 is an operational system. It was developed jointly by Canada, the U. K., and Federal Republic of Germany, and is used by all three countries. The Italian Army is interested in the system as well as the U. S. Army. Details with regard to the configuration and operational characteristics of this vehicle appear in the Handbook.

(U) The chief designer of this unusually configured vehicle was Mr. John P. Kerr of Canadair. Development was completed in early 1968. Canadair has plans to improve the present drone, which is simply pre-programmed for a constant-altitude flight profile and has a relatively short range. Improvement plans include:

- Extending the range by increasing the fuel capacity of the drone.
  - Prototype development is planned.
- Developing a variable-altitude profile capability.
  - Prototype development is planned.
- Developing a real-time data transmission system.
  - A feasibility study is planned.
- Developing a long-range system by extending the fuselage and increasing the wing area.
  - Plans are indefinite.

(U) The cost of the complete CL-89 support system is approximately $2 million. The actual drones represent additional costs based upon the number required. A typical cost was not cited, but another source indicates that it is approximately $60,000 per drone.

CL-227 (U)

(U) The CL-227 is a proposed helicopter drone. It has the appearance of a can with two contra-rotating propellers located at the top. It will be remotely controlled and is a free (untethered) system.

(U) The system would carry one sensor (such as an MTI radar) at a time and would have a real-time data transmission capability. According to Mr. Price, the U. S. Army Combat Developments Command at Ft. Belvoir was interested in this system. However, no prototype has been built.

Periscopter (U)

(U) In the mid-1960s, Canadian Westinghouse developed a tethered helicopter-type platform powered from a ground station. An operational version exists, but work was discontinued on the program in 1967 due to a lack of interest and support by potential users, such as the U. S. Army. The vehicle was flown at 100 ft., but had poor stability in bad weather. Mr. David Helm of the U. S. Army Night Vision Laboratory is aware of this system.

(U) Mr. Price could not release the Canadian Market Survey of Drones conducted by Mr. John Walker because it is proprietary in nature.

APPENDIX C

A SYNOPSIS OF RECENT ARMY HISTORY IN THE FIELD OF DRONE AIRCRAFT DEVELOPMENT/UTILIZATION (U)

APPENDIX C

## A SYNOPSIS OF RECENT ARMY HISTORY IN THE FIELD OF DRONE AIRCRAFT DEVELOPMENT/UTILIZATION (U)

(C) Prior to 1964, the Army was the front-runner among the Military Services in the development and utilization of drone aircraft for surveillance and target-acquisition missions. In 1964, the Army Chief of Staff decided (by Summary Sheet action) to discard the existing Army R&S drone aircraft and to rely upon the Air Force for tactical aerial surveillance and target detection. At the same time, however, he directed certain agencies of the Army to maintain a data base on drone-aircraft systems that might be applicable later to Army missions. The reasons for this decision were described as follows:

- The costs of the drone aircraft (development, training, operation, recovery) were just too high in terms of personnel as well as funds when viewed from the standpoint of their limited utility for surveillance/target-detection missions.

- The performance of the early drone aircraft systems for special surveillance/target-detection missions did not approach that of manned aircraft for the same missions. Moreover, manned aircraft could perform other aerial reconnaissance/spotting missions.

- The field training and deployment of the early drone aircraft systems presented difficult mission and operational problems with respect to other Army/Air Force aircraft.

- Although the requirements for the early drone aircraft stressed the need for simplicity in operation and maintenance, the various user demands for a "gadget-to-do this and a gadget-to-do-that" inevitably resulted in the production of drone aircraft systems that were overly complex for tactical operations.

- The Army was reassured by the Air Force that the latter could perform all of the Army's tactical surveillance/target-detection missions with their own manned aircraft much more efficiently and <u>at no apparent cost to the Army</u>.

(C) As was discussed in the section of this report on the assessment of requirements, the Army is reconsidering the use of drone aircraft or aerial platforms for surveillance and target-acquisition purposes. Highlights of this reassessment are as follows:

- The Army was not satisfied with the Air Force's responsiveness and effectiveness in supporting the Army's tactical aerial surveillance/target-detection mission requirements. It appeared that the Air Force was primarily interested in the development and employment of drone aircraft systems for long-range strategic missions.

- The Army did not give up testing and evaluating certain aerial platforms (such as the ARPA-sponsored DASH helicopter) for surveillance/target-detection purposes.

- The Army will be initiating studies designed to identify the best hardware solutions to the aerial surveillance requirements defined in the STANO Resources Management Study. A major reservation with respect to STANO Resources Management Study is that it attempts to suggest immediate solutions to the requirements defined therein.

APPENDIX D

# TETHERED AND HOVERING OBSERVATION FLIGHT PLATFORMS (U)

APPENDIX D

## TETHERED AND HOVERING OBSERVATION FLIGHT PLATFORMS (U)

(U) The U. S. Army's Advanced Materiel Concepts Agency (AMCA) has developed a concept paper for an Elevated Target Acquisition System (ELTAS). The evaluation of this concept has progressed to the stage of a preliminary systems engineering design study. The ELTAS flight vehicle would be an unmanned, electrically-powered, counter-rotating, rotary-wing, tethered platform. The vehicle would carry approximately 200 lb of primary mission equipment, including a laser target designator, and would operate at elevations up to 1,000 ft. The necessary electrical power and critical data links would be provided through the tether.

(C) Although the prime mission of ELTAS would be target designation and acquisition, it is representative of a long-standing general requirement for an aerial observation system that:

- Requires minimum set-up time and is almost instantaneously ready.
- Is self-contained to the point that the flight vehicle and its (minimum) associated ground equipment can be moved as a unit.
- Requires no site preparation in that the prime mover is also the launch and retrieval pad.
- Provides a continuous data link to the ground center.
- Possesses essentially all-weather and day-night capabilities, though its operations may be sensor-limited.
- Has long mission endurance.

(U) Over the past few years, a number of developers have recognized these general requirements and have undertaken to develop platforms that would be suitable as the basic flight vehicle. One concept proposed by General Dynamics involved a free hovering platform based upon a ducted fan propulsion principle. The tethered platform gives the hard link to the ground station and the long endurance can be achieved by supplying electrical power or even fuel through the tether. Dornier's Kiebitz is the most publicized example of this type of system and it is probably the most advanced conceptually and developmentally.

(U) All of the developmental tethered platform systems have encountered vehicle stability problems. None of the concepts has involved a vehicle in which the counter-torque problem was solved in the conventional helicopter fashion using a counter-torque auxiliary rotor. In fact, the most of the concepts do not involve the use of helicopter-type, large-diameter rotors. Some have attempted to use relatively high-disk-loading, counter rotating propellers (e.g., the QH-50) and ducted fans. The Kiebitz, the ELTAS concept, and the Marchetti Heliscope are closest to being rotating wing-type vehicles. The Kiebitz uses tip jets to drive the rotor, thus avoiding the counter-torque problem. The Marchetti vehicle and several others use counter-rotating electric motors to drive propellers or rotors. Stability problems have been common. Most of the systems, the Kiebitz included, have not attained the all-weather objective which has been established for these systems. Most have been unsuccessful in all but relatively low winds. There is also evidence that the small-amplitude unsteadiness and vibrations inherent in the use of these platforms have raised doubt about their compatibility with certain sensors. Most of the tethered platform developments have not been able to achieve the endurance objectives, even though the energy is continuously supplied from the ground. Basically, this is a reliability problem.

(U) Figures D-1 through D-6 reflect the spectrum of platforms of this type that have been considered or are under development. Kiebitz has not been included in this summary because it is covered more completely in the Handbook. The ELTAS concept is included in the summary for comparison purposes.

(C) In October 1969, the Army Combat Developments Command established an approved Advanced Development Objective (ADO) for an Unmanned Aerial Surveillance System (UASS). Apparently, a helicopter type of vehicle was envisioned, probably inspired by the Canadair CL-227 concept. This ADO is informative in that it sets forth a rather ambitious set of requirements. No vehicle of any type under consideration today can meet the complete spectrum of these requirements. A unique pop-up profile for the vehicle is prescribed in order to reduce vulnerability; i.e., it moves from observation station to observation station at very low altitudes and then pops up for data-gathering. Unfortunately, this profile would dictate a helicopter for all practical purposes, and would preclude consideration of other (cruise-type) drone vehicles that might achieve acceptable survivability by other means.

(C) Some of the essential features of the vehicle described in this ADO are:

- Real-time combat surveillance information
- Capable of hovering and transition to forward flight
- Fully variable flight speed from hover to maximum speed
- Pop-up mode mission profile
- Hover altitude: 10,000 ft.
- Hover endurance (10 percent fuel reserve): 75 minutes
  – Sufficient range is assumed by the combination of 100 kt maximum speed and 100 minutes maximum operation time
- Minimum rate of climb: 3,000 ft/min
- Maximum speed: 100 kt

D-3

Elevated Target Acquisition System (ELTAS)

U. S. Army Advanced Materiel Concepts Agency

Counterrotating, rotary-wing, tethered platform

Weight, 300 lb; payload, 200 lb

Elevation, 1,000 ft

Status: Conjectural - Preliminary systems engineering design/ evaluation study

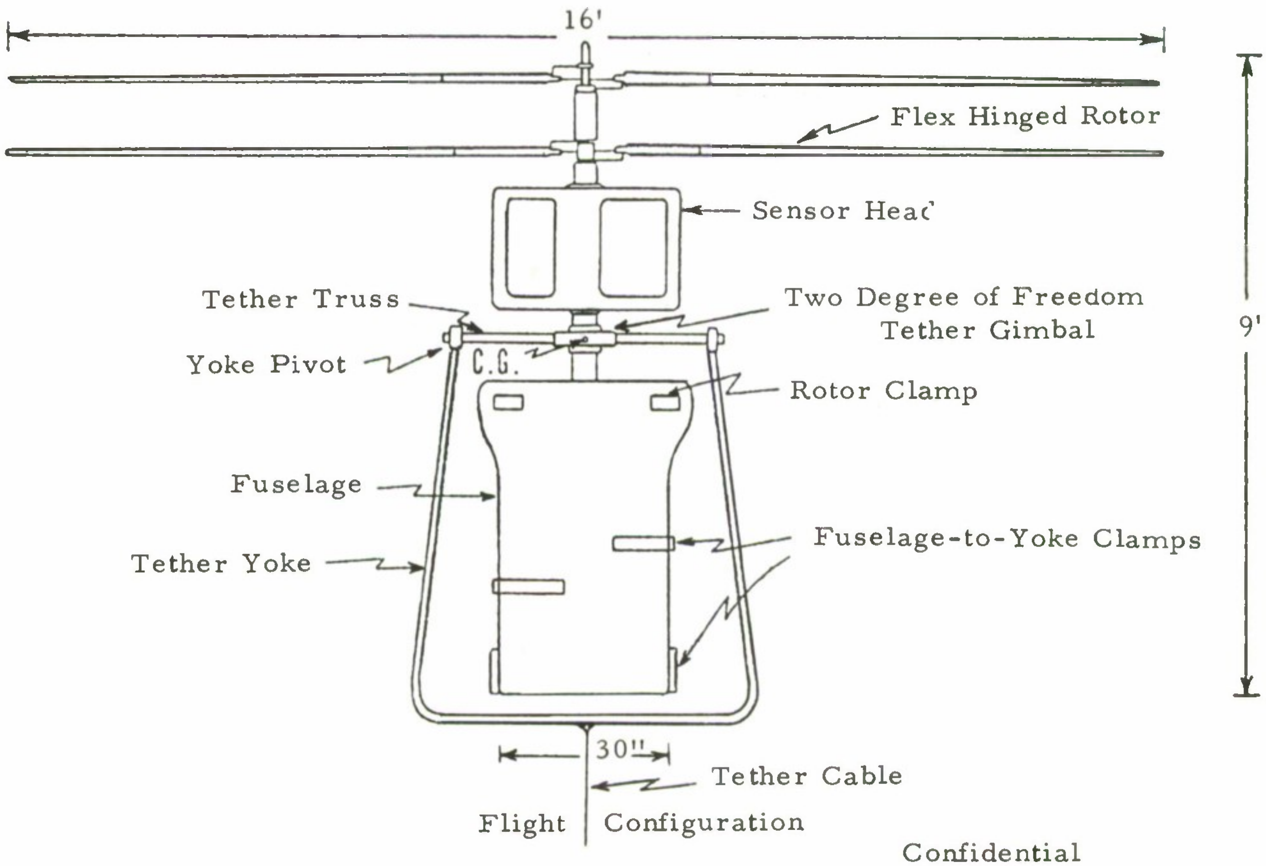



FIGURE D-1. ELTAS TETHERED PLATFORM (U)

## Periscopter

Canadian Westinghouse
Rotating wing, tethered, electric motor powered
Weight, 500 lb; payload, TV camera
Service ceiling, 600 ft
Status: Developmental (see coments in discussion of Canadian activities)

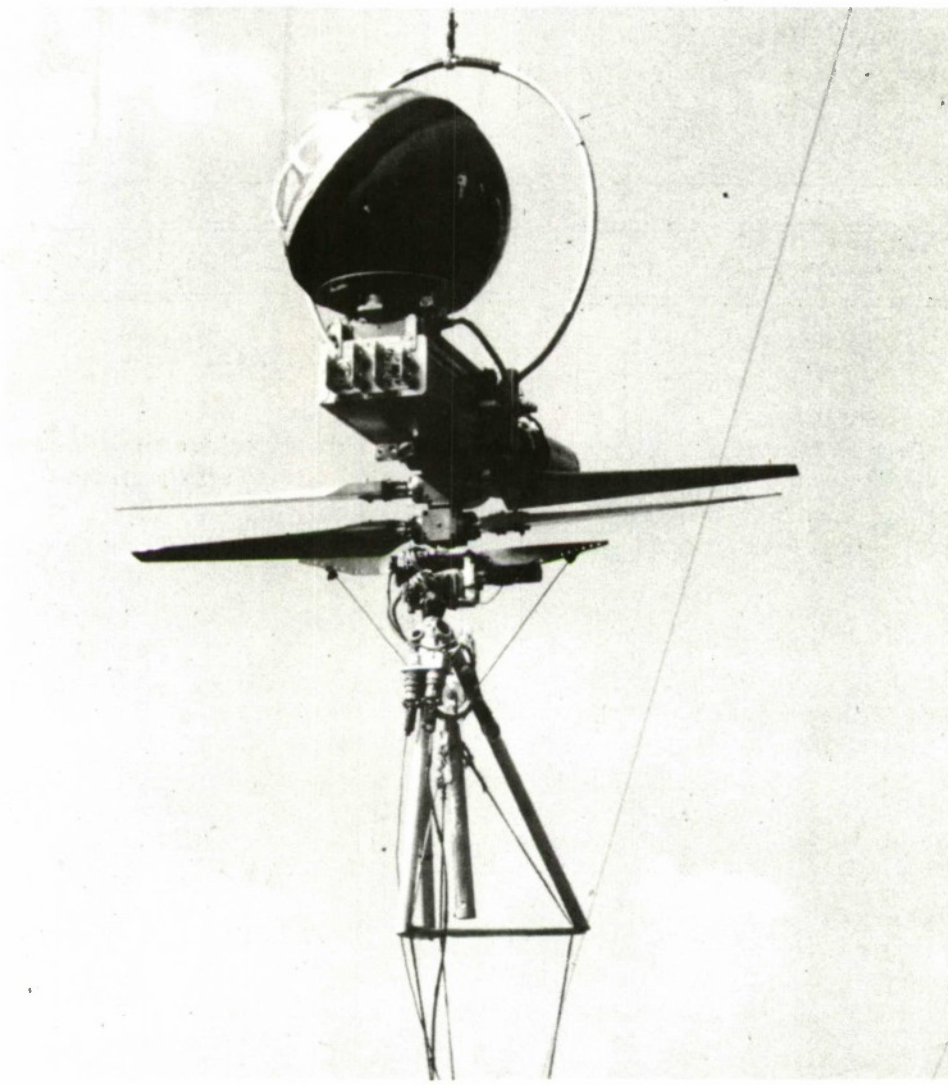
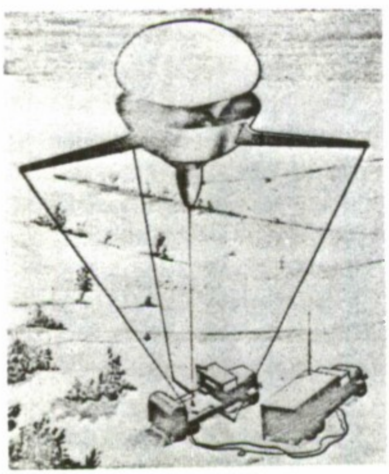


FIGURE D-2. PERISCOPTER TEST VEHICLE (C)

## Nord 510

Nord Aviation (France)
Shrouded propeller, tethered
Weight, 990 lb; payload, 800 lb
Altitude, 1,000 ft
Status: Development terminated



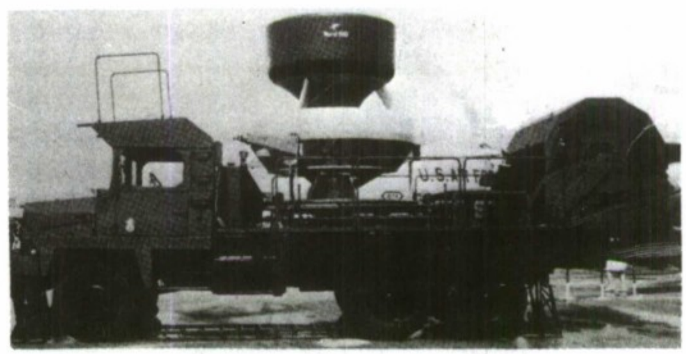


FIGURE D-3. NORD 510 (U)

## Marchetti Heliscope

Société Charles Marchetti

Rotating wing, tethered, electric motor powered

Weight, 286 lb (max.)

Status: Developmental

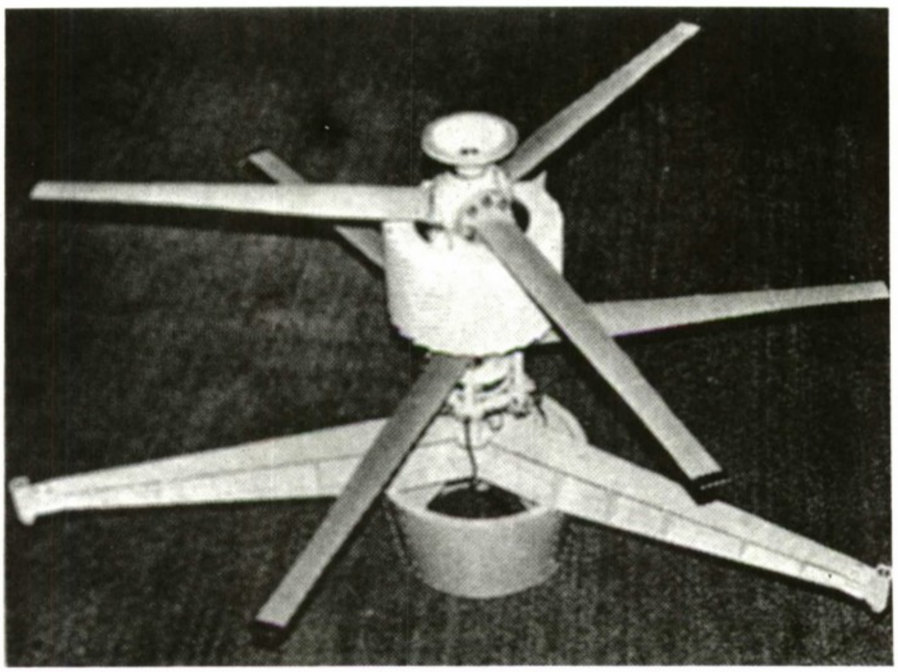


FIGURE D-4. MARCHETTI HELISCOPE (U)

Tracy Teknocraft Tethered Platform

Tracy Teknocraft - Formerly Military Systems Division of U. S. Industries

Rotating wing, tethered, electric motor (two 5-hp) powered

Weight, 125 lb; payload, TV camera

Service Ceiling, 2,000 ft

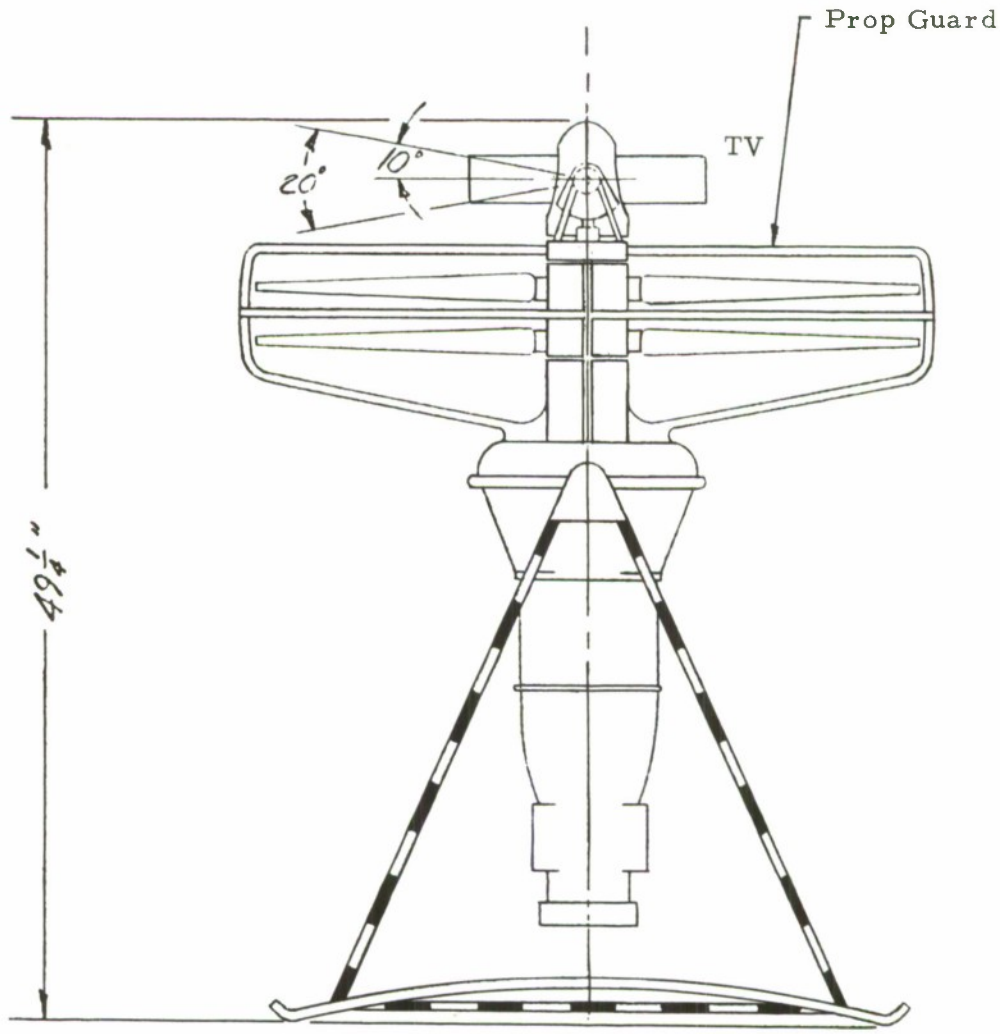



FIGURE D-5. T. T. TETHERED PLATFORM (U)

## LALO

Convair GD

Ducted Fan, Hovering

Weight, 615 lb; payload, camera (62 mm)

Service ceiling, 19,000 ft

Status: Concept circa 1965 – no development

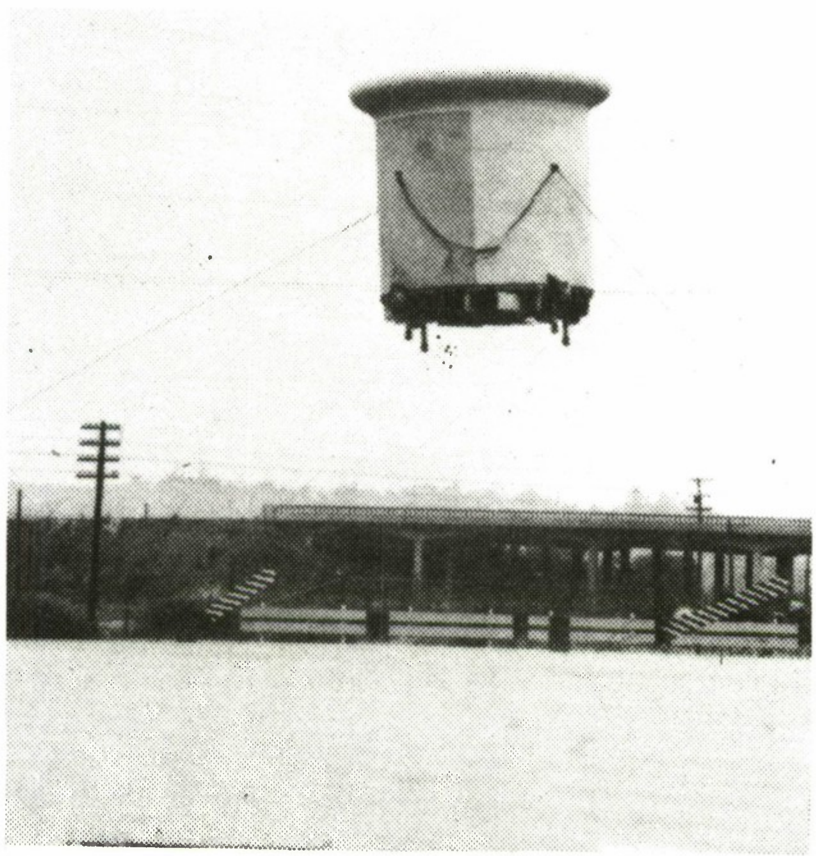


FIGURE D-6. LALO CONCEPT (U)

- Minimum operational time (10 percent fuel reserve): 100 minutes
- Service ceiling: 16,000 ft.
- Readiness capability: 10 minutes
- All-weather operational capability
- Electronic link to the ground control station
- Contains fixed and MTI radar
  - Stability compatible with MTI sensor
- Minimum noise
  - Minimum vulnerability design and configuration
- Automatic re-acquisition procedure
- Helicopter liftable
- Unprepared site operation
- Minimum maintenance required
  - Quantitative measures were specified
- Operational by FY 1975.

(U) It is interesting to apply this set of objectives to the potential capabilities of tethered platforms, noting that an area coverage capability is lacking with any tethered platform. Otherwise, the platforms could be suitable and also have many of the important features described in the foregoing objectives.

(U) For the past 7 or 8 years, there has been a sporadic development effort by Raytheon to develop a microwave stabilization system and microwave motor for unpiloted (electric) helicopters. With a properly shaped beam and receivers mounted on the vehicle, it is possible, in theory, to sense the vehicle attitude and c.g. displacements and to control it accordingly. The system has been demonstrated under ideal conditions and negligible altitude using a small, model, helicopter-configured platform, but without the beamed-power, microwave motor feature, which is only postulated. Under more adverse conditions, there has been difficulty with the stability of the vehicle in the beam. Generally speaking, the concept is not particularly viable at this time and is not considered to have much potential for improving the capabilities of observation platforms in the foreseeable future.

APPENDIX E

SMALL, SIMPLE, INEXPENSIVE DRONE SYSTEMS (U)

# APPENDIX E

## SMALL, SIMPLE, INEXPENSIVE DRONE SYSTEMS (U)

(U) There are a number of very small, simple, and inexpensive drone systems either in existence or proposed. In general these do not appear to be appropriate for R&S missions. However, there may be certain limited missions that these vehicles could undertake and for this reason they are covered here.

(C) The Bikini drone is probably the most rudimentary vehicle presented in the Handbook. In appearance and performance it resembles a large model airplane. Pre-prototype versions of the vehicle were based on construction techniques and componetry found in the radio-control model, hobby industry. The operational vehicle, however, was all metal construction, ruggedized and considerably engineered. It was operational with the USMC, but is now out of use and has been judged to be obsolete relative to the modern requirement for high-endurance (USMC may require as much as 4 hours) vehicles. The Bikini and similar low-payload vehicles also cannot accommodate the equipment and instrumentation associated with such requirements as night time observation, MTI's, real-time surveillance, and high position accuracy. Experience suggests that these requirements demand a vehicle sophistication, and undoubtedly a system cost, considerably beyond the Bikini-type of approach. (Bikini, for example, could carry only a camera and film for a few frames.) The typical time required for recovery and development of the film was approximately one-half hour, and the Binini system cost approximately $4,000.

(U) A number of concepts for other elementary, low-cost vehicles have been put forward in the past, and there are current proposals for essentially this type of "solution" for short-range, battlefield surveillance. For example, the following article appeared in the Armed Forces Journal, May, 1971:

> "Sweden is developing a small reconnaissance drone, not much bigger than a model aircraft and similarly controlled.
>
> "A prototype, fitted with a small camera, is at present carrying out trials. Its speed is only 50 mph and its range is limited by how far the controller can see, but it is hoped in the future to have some form of automatic guidance.
>
> "To go in the final version Sweden is adapting the type of camera used by the Apollo astronauts, called the 'Lunar Surface Camera', which can make 70 exposures with a focus of 150 mm.
>
> "The drone is for battlefield surveillance. Because of its small size it is difficult to detect by radar."

(C) Gyrodyne, USA, has proposed the development of a drone helicopter along the lines of the Junior Dash. Del Mar Engineering has proposed a system (apparently a junior Whirlymite) known unofficially as the Woods/Sanctuary. This system is not included in the Handbook. This is not meant to imply that these systems will be unjustifiable or unsuitable for certain unique missions. However, they will be vehicles of limited sophistication and relatively low payload, and therefore will have capabilities that are too limited for the extensive spectrum of modern combat surveillance requirements.

(U) High-treat environments may, of course, demand a compromise of sophistication and cost reduction; however, there is a practical limit to the value of this compromise. The risk of loss due to other aspects of typical drone operation, such as recovery failures and loss of the vehicle due to navigational failures, also create a pressure for cost reduction and add to the dilemma of the cost-sophistication compromise. As far as can be determined, no attention has been given to the idea of R&S drone design for optimum cost, with due consideration to the threat environment and hence the expected number of uses, versus the mission value and the quality of mission performance as a function of vehicle and sensor sophistication. This is probably a consequence of the fact that most R&S drone developments have been modifications of target drones. Accordingly, many of these valuable tradeoff considerations have been automatically precluded, at least for the flight vehicle and allied portions of the system.

(U) Figures E-1 through E-5 show a few of the "typical" rudimentary vehicle concepts that have been proposed for the short-range surveillance mission. None of these is now considered to be a viable concept. All of the systems shown here were reported in the 1967 ECOM survey of drones, although most of these concepts were part of circa 1964 proposals, some under an ECOM small drone study. It is believed that most of the combat surveillance vehicles being proposed or developed today represent a much better appreciation of the requirements of this mission class on the part of potential users and developers. However, going to the other extreme, ambitious requirements have been postulated in the past few years that are beyond the capability of any identifiable condidate vehicle in the picture today. This situation will be discussed in Section III.

E-3

Flexbee

Ryan Aeronautical

(Bikini Competitor) Fixed wing cruise

Gross weight, 79 lb; payload, 15 lb (Aerial Camera)

Service ceiling, 17,000 ft; radius of operation, limited by controllers visual ability

Radio command guidance; typical speed, 65 mph

9 hp, reciprocating engine; recovery, landed

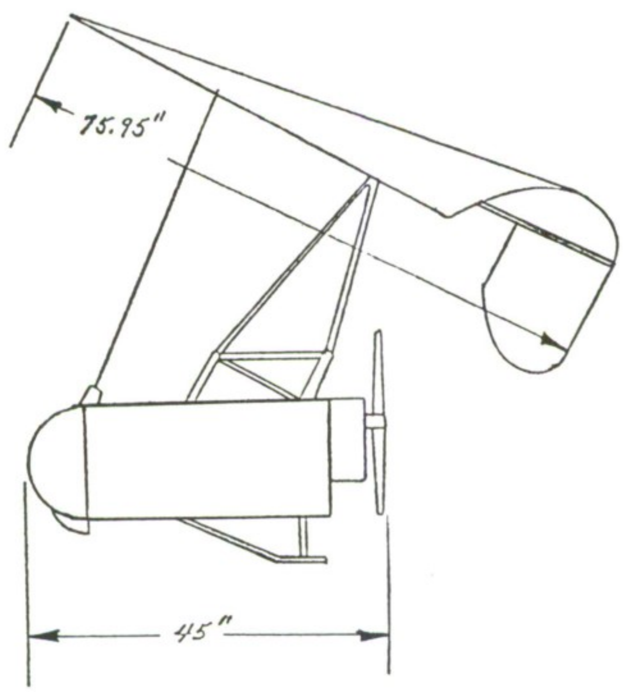



FIGURE E-1. FLEXBEE (U)

## Tattle-Tale

Aerojet General

Deployable wing, boosted glider

Gross weight, 62 lb; payload, 70 mm camera, 25 frames

Service ceiling, 15, 000 ft; radius of operation, 6, 000 meters

Unguided, radio command for recovery; typical speed, 47 mph

Solid rocket plus gas generator; recovery, flown in

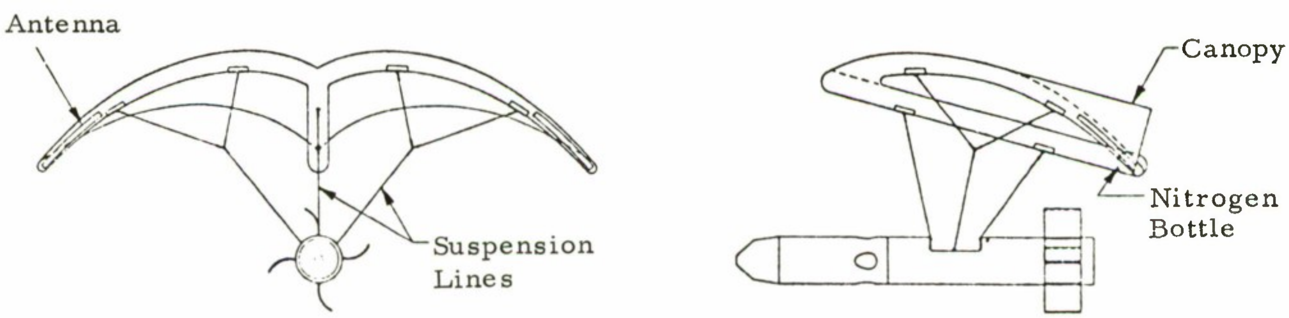



FIGURE E-2. TATTLE-TALE (U)

E-5

Boomerang

Bendix

Fixed wing cruise

Gross weight, 100 lb; payload, 70 mm camera

Service ceiling, 10,000 ft; radius of operation, 10 miles

Programmed guidance; recovery, parachute

Ramjet propulsion; speed, 454 mph

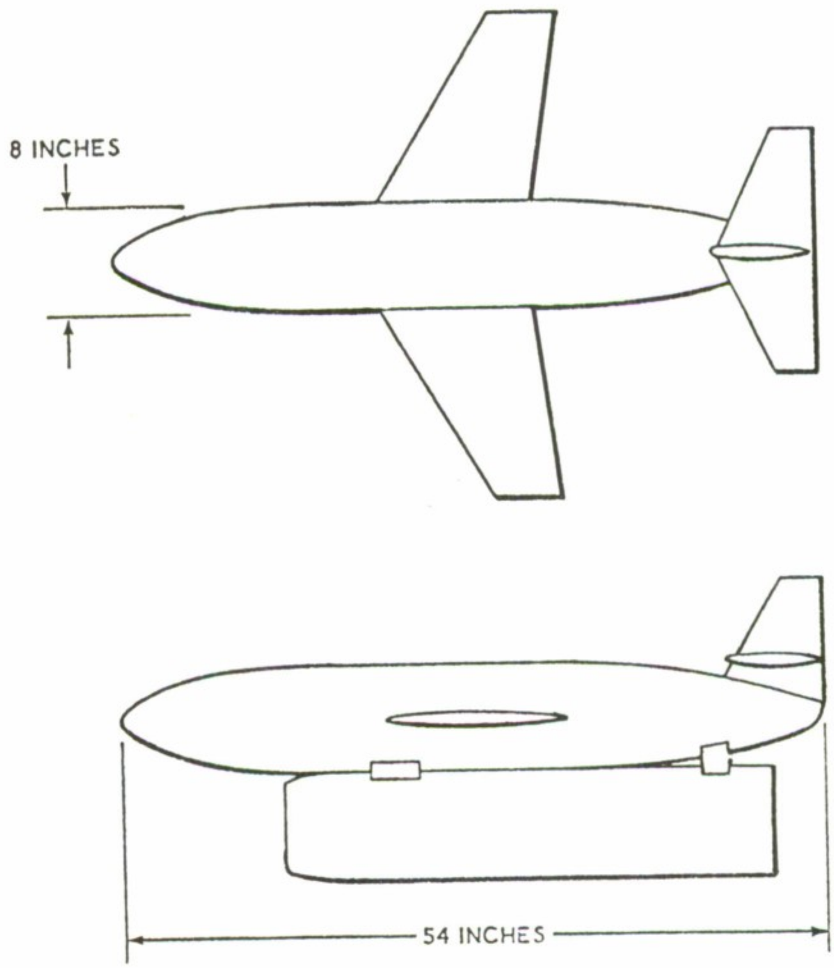



FIGURE E-3. BOOMERANG (U)

E-6

Peeping Tom

Beech craft

Fixed wing, rocket boosted glider

Gross weight, 100 lb; payload, 5 lb

Service ceiling, 2,000 ft; radius of operation, 8,000 meters

Programmed guidance; recovery, parachute

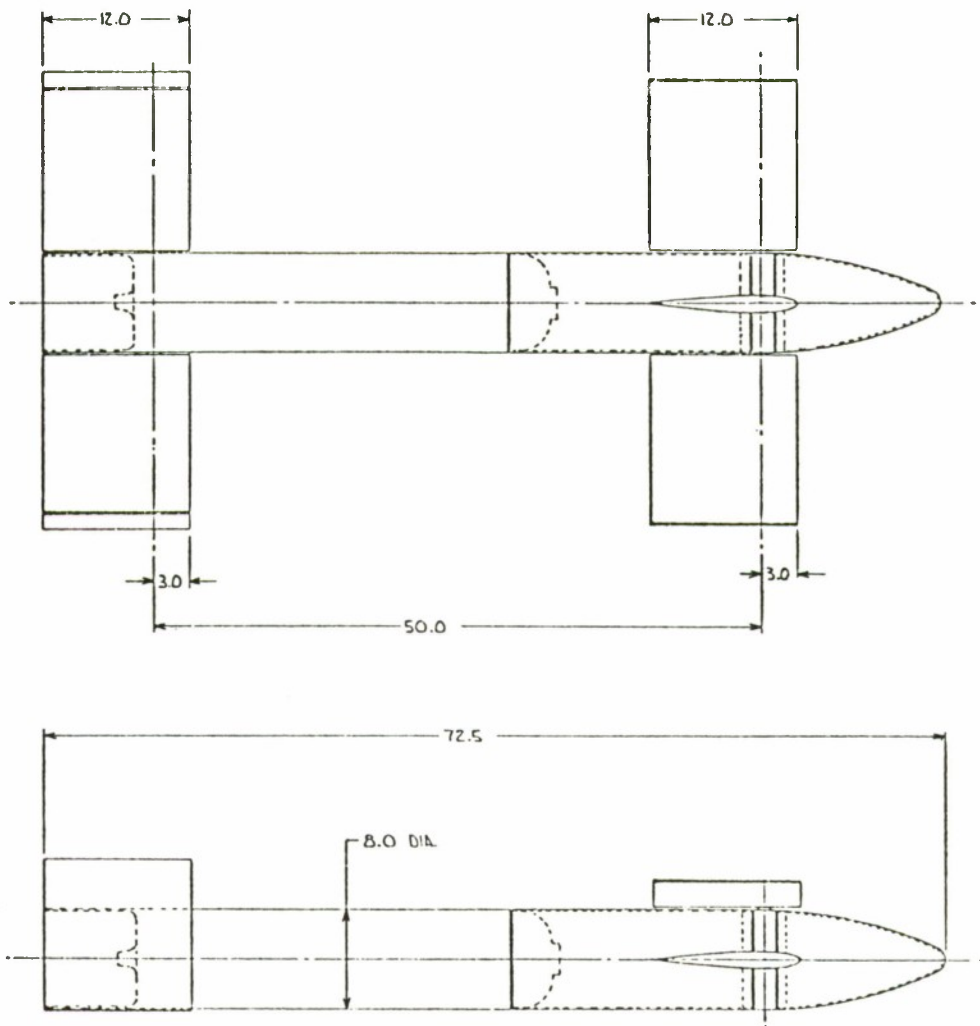



FIGURE E-4. PEEPING TOM (U)

E-7 and E-8

SRASS
(Short Range Aerial Surveillance System)

Cornell Aeronautical Laboratory

Ducted propeller

Gross weight, 60 lb; payload, 10 lb

Radius of operation, 4 miles; speed, 200 kts

Programmed guidance; recovery, landed

Launched from rail with shock-cord, sling-shot type system

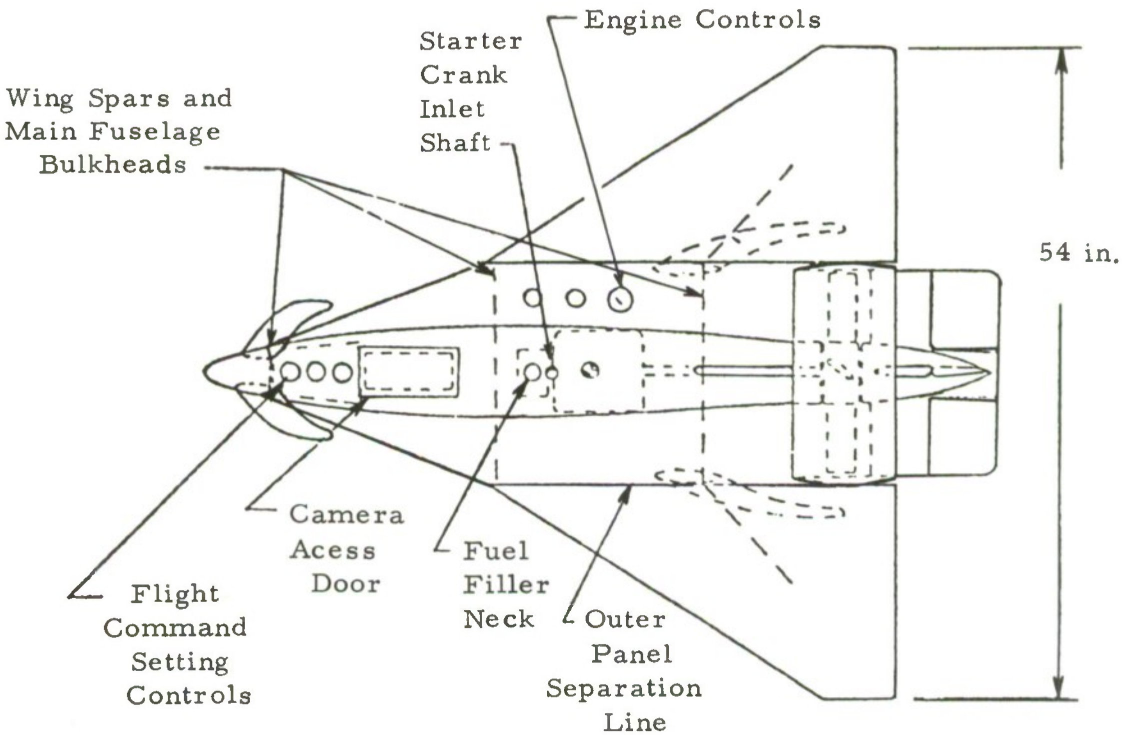



FIGURE E-5. SRASS (U)

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13. ABSTRACT

A survey and technical assessment of 81 drone vehicles for tactical reconnaissance and surveillance (R&S) missions are presented. A great many of these vehicles are determined to be unsuited for R&S missions because of high speed, limited range, outdated technology, excessive cost, or vulnerability. The development of new drones and the adaptation of existing drones for R&S missions is discussed. A bibliography containing 78 references is included.

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| Reconnaissance | 8 | | | | | |
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| Wankel engines | 4 | | | | | |
| Evaluation | | | 8 | | | |
| Bibliography | | | 8 | | | |
| Reviews | | | 8 | | | |